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DETECTION PERFORMANCE OF THE AN/TPN-19
PAR (PRECISION APPROACH RADAR)

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20. improving the MTI performance are given and evaluated.

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DETECTION PERFORMANCE OF THE AN/TPN-19 PAR

Vincent C. Vannicola

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FOREWORD

This report describes the detailed solution of a difficult theoretical problem which is directly related to an Air Force radar system currently in development. The system is the AN/TPN-19 Landing Control Central and more specifically, the *Precision Approach Radar* (PAR) for that system. The research was accomplished under Job Order 404L0004.

It has been known for many years that when a typical radar is operated in an anti-clutter or *Moving Target Indicator* (MTI) mode, its detection performance drops with respect to that obtained in a normal scan mode for the same radar. Even though the existence of this loss in detection performance was known, the closed-form theoretical solution and precise quantitative effects have not been carried out or published to date.

The main body of this report is a very careful delineation of the problem and the development of a rigorous closed-form solution which yields quantitative results. This method can be adapted to provide quantitative results for numerous other radar problems.

This report has been reviewed by the RADC Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

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ABSTRACT

The purpose of this report is to determine the receiver operating characteristics of the AN/TPN-19 PAR Air Force radar in some of its operating modes. The scan mode and the coherent MTI (*Moving Target Indicator*) mode will be considered for the case when the received target signal is corrupted by white Gaussian noise only. The MTI loss (the increase in signal-to-noise ratio required for the same detection performance when switching from the scan mode to the MTI mode) is also determined and discussed. Methods for improving the MTI performance are given and evaluated.

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INTRODUCTION

The TPN-19 PAR has primarily three modes of operation: a scan mode employing post detection integration, a coherent MTI, and a non-coherent MTI mode both of which use a non-recursive 2-pulse delay digital canceller. The modes differ to the extent the received signal is processed. This report will cover the performance of the scan and coherent MTI mode when the signal is corrupted by thermal noise only. The signal-to-noise ratio that is required for various detection probabilities will be determined.

The radar scans the coverage with a raster, transmitting six pulses per beam position. Each beam overlaps in coverage with adjacent beams so that the target may be detected in one or more of these beams during a single scan.

The probability that a target is detected is equal to the probability that the received signal crosses a set threshold in at least one of the beams, adjacent or otherwise. This detection criteria applies to all three modes of operation.

For the scan mode all six pulses per beam position, each three at an independent center frequency, are received through separately tuned receivers, square law detected, and integrated. The sum of these six pulses represents a variable which is tested against a threshold and accepted or rejected as a target.

For the coherent MTI mode, six pulses are transmitted per beam position, each three at an independent center frequency. These are received through two receiver channels each tuned to the appropriate center frequency. Each group of three received pulses are video detected, i.e., down converted to zero IF, passed through a three-pulse canceller, gated, and then made positive by squaring or taking its absolute value. These outputs of the two receiver channels are added and this sum is tested against the threshold. The adjacent beam operates in like manner except the PRF of the six pulses is different and the center frequencies are also different. The different PRF has the effect of avoiding blind speeds since the target will always appear in the visible portion of the spectrum in at least one of the beams. The additional independent frequencies provide the system with diversity gain.

When the second raster scan takes place, the PRF and frequency occur at alternate beam positions. The scanning cycle is then considered complete.

In this report the performance of the scan mode and the coherent MTI mode are each evaluated and a comparison is made as to their relative performance. Also evaluated herein is the performance of the MTI mode if the received signal were to be video detected in both the in-phase and the quadrature-phase channel, i.e., " $I^2 + Q^2$ ". (Note: The present AN/TPN-19 PAR processes the in-phase channel only: "I Only").

We shall first evaluate the scan mode.

SCAN MODE

When the system is operating in the scan mode, three pulses are received at each of two independent frequencies. These six pulses are each square law detected and video integrated. The target is assumed to be a Swerling Case I* at any one frequency. Thus each beam position gives a total of six square law detected signals containing two independent Rayleigh samples. The probability density function of the output variable, Y, and the probability of detection is derived in Appendix A.

We assume that the target is located anywhere within a beam with uniform probability and that the beams overlap as shown in Figure 1. We determine a composite[1] detection probability by first determining the conditional probability of detecting the target in either of the beams at some particular target location. Next we average the detection probability throughout all locations within the coverage. This can be done very effectively by determining the detection probability at each of ten (10) points within the triangle of symmetrical coverage shown in Figure 1 and averaging the results.

*A Swerling Case I target has a slow fluctuating Rayleigh distributed return.

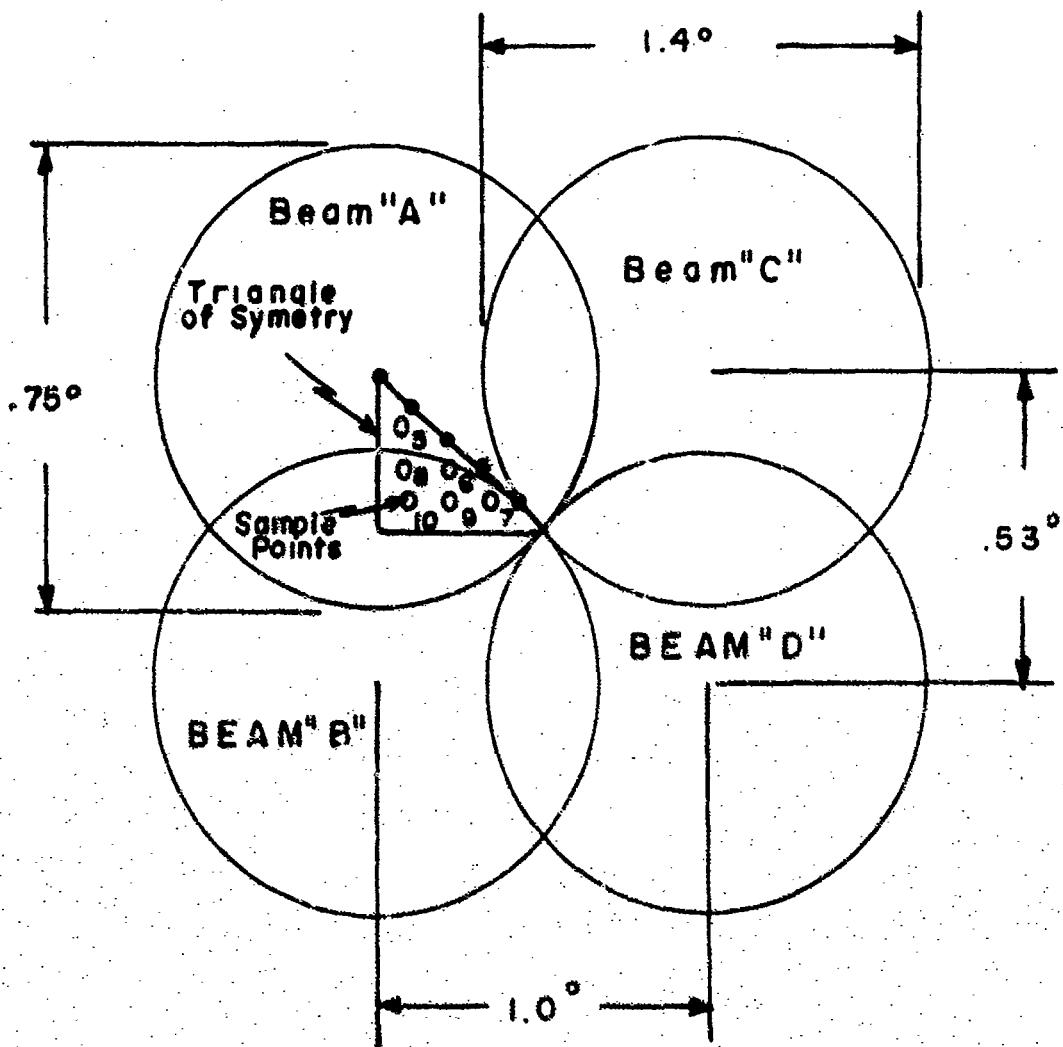


Figure 1. Relative Beam Positions of PAR.

Since the output variable, Y , is dependent on beam position, ℓ , and target location, ϕ , we denote the conditional detection probability, i.e., that the output variable Y crossed the threshold γ of beam L by $P_{DL}^1 | \phi, H_1 (Y > \gamma | \phi, H_1)$.* Note that velocity dependence does not apply for the scan mode.

The probability that a target is detected in at least one of the K beams, i.e., either in beam A, or B, or C, etc., or any combination thereof is

$$P_{D^1} | \phi, H_1 = 1 - [1 - P_{DA}^1 | \phi, H_1 (Y > \gamma | \phi, H_1)] [1 - P_{DB}^1 | \phi, H_1 (Y > \gamma | \phi, H_1)] \dots \\ \dots [1 - P_{DK}^1 | \phi, H_1 (Y > \gamma | \phi, H_1)] \quad (1)$$

provided that the return signal from each beam is independent.

*The symbol H_1 refers to hypothesis 1, i.e., the target is present. Likewise H_0 refers to the target is not present.

Averaging over the scan triangular sector

$$P_D = \frac{1}{10} \sum_{j=1}^{10} P_D | \phi_j \quad (2)$$

where the pdf of target location is assumed to be discretely uniformly distributed.

COMPUTER RESULTS FOR SCAN MODE

In computing the position and beam dependent probabilities of detection the amplitude weighting factors $GA(j)$, $GB(j)$, ..., and $GL(j)$ for position j and beam A , B , ..., and L , respectively, were provided by the contractor, Raytheon and are shown listed in Table I. In the scan mode beams E, F, G, and H are redundant in space coverage but occur one-half second later. Equation (2) was computed for the values of false alarm and signal-to-noise ratio in dB as indicated. Several beam combinations are shown. The values are given in Tables II through IV. The detection probability for the target located at the center of beam "A" and "A and/or E" is shown in Tables V and VI respectively.

COHERENT MTI MODE

In order to keep the terminology simple in the derivations of the probability density functions for the different receiver models to be evaluated, beam center values and velocity dependent target signals will be used. The situation will be generalized for position, velocity, and beam averaging later in the report.

VELOCITY DEPENDENT SIGNAL ON BEAM CENTER

The received signal is assumed to be a Swerling Case I waveform with the further condition that a random bit correlated phase is present from pulse to pulse in any three pulse bursts. The phase is modulated by the target radial velocity. The signal is corrupted by white Gaussian noise with power spectral density $N_0/2$.

For a single pulse the RF received signal may be written [1].

$$H_1: r(t) = v \sqrt{\frac{2}{\tau}} \operatorname{rect}\left\{\frac{t}{\tau}\right\} \cos [w_0 + w_d] t + \theta + w(t) \quad (3-A)$$

when a target is present, i.e., hypothesis H_1 holds, and

$$H_0: r(t) = w(t) \quad (3-B)$$

when there is no target present.

We know that for a Swerling Case I target the amplitude v in Equation (3) has a Rayleigh distribution and the phase θ has a uniform distribution. The function

$$\sqrt{\frac{2}{\tau}} \operatorname{rect}\left\{\frac{t}{\tau}\right\} \quad (3)$$

corresponds to the waveform envelope and is normalized so that the energy in the received signal is v^2 . The quantities w_0 and w_d represent the RF center frequency and the doppler frequency, respectively, and the function $w(t)$ is white Gaussian noise present in the receiver.

After the received signal is sufficiently amplified above the noise level of subsequent stages it is eventually down converted (see Figure 2) by the following normalized operation.

$$r_0 = \int_{-\frac{T}{2}}^{\frac{T}{2}} r(t) \sqrt{\frac{2}{T}} \cos w_0 t dt \quad (4-A)$$

giving

$$H_1: r_0 = v \cos \theta + n_0; w_d \tau \ll 1 \quad (4-B)$$

$$H_0: r_0 = n_0$$

It can be shown [2] that when v is Rayleigh with $E[v^2] = 2\sigma_s^2$ and when the noise $|w(t)|$ is Rayleigh with $E[|w|^2] = N_0$ then $v \cos \theta$ is Gaussian with variance σ_s^2 and n_0 is Gaussian with variance $N_0/2$. Since $w(t)$ is a narrow band white Gaussian process with power spectral density $N_0/2$, the envelope $|w(t)|$ is Rayleigh with $E[|w|^2] = N_0$.

It also can be shown that the preceding pulse takes on the form

$$r_1 = v \cos(-w_d T + \theta) + n_T \quad (4-C)$$

and the preceding pulse

$$r_1 = v \cos(w_d T + \theta) + n_T \quad (4-D)$$

The variables n_T, n_0, n_T are each independent.

When each variable r_i occurring at time i it is fed through the three-pulse canceller having an impulse response

$$h(\tau) = -\delta(\tau + T) + 2\delta(\tau) - \delta(\tau - T) \quad (4)$$

then the resulting variable at the output of the canceller at the time the last variable t_1 is feeding the input can be written

$$\begin{aligned} H_1: r &\approx 4 \sin^2 \left(\frac{w_d T}{2} \right) v \cos \theta \cdot n_T + 2n_0 \cdot n_T \\ H_0: r &= -n_T + 2n_0 \cdot n_T \end{aligned} \quad (5)$$

where the noise terms may be grouped into a single term, n , with variance $3N_0$ and the variance of the signal at the output of the canceller is $16 \sin^4(w_d T/2) \sigma_s^2$. Both these terms are zero mean Gaussian random variables.

In the system under analysis the output of the canceller is gated on during the interpulse period immediately following the third input pulse. Therefore the observed variable under each hypothesis is zero mean Gaussian with pdf as follows

$$p_r |_{w_d, H_1} (R | \Omega_d, H_1) = \frac{1}{\sqrt{2\pi}\sigma_1} \exp \left(-\frac{R^2}{2\sigma_1^2} \right) \quad (6-A)$$

$$p_r |_{H_0} (R | H_0) = \frac{1}{\sqrt{2\pi}\sigma_0} \exp \left(-\frac{R^2}{2\sigma_0^2} \right) \quad (6-B)$$

where

$$\sigma_1^2 = 16 \sin^4 \left(\frac{\omega_d T}{2} \right) \sigma_s^2 + 3N_0$$

$$\sigma_0^2 = 3N_0$$

and σ_s^2 is the mean square signal returned from the target scatterer in one Gaussian channel, ($v \cos \theta$). This channel will also be referred to as the "I Only" channel, as shown in Figure 2.

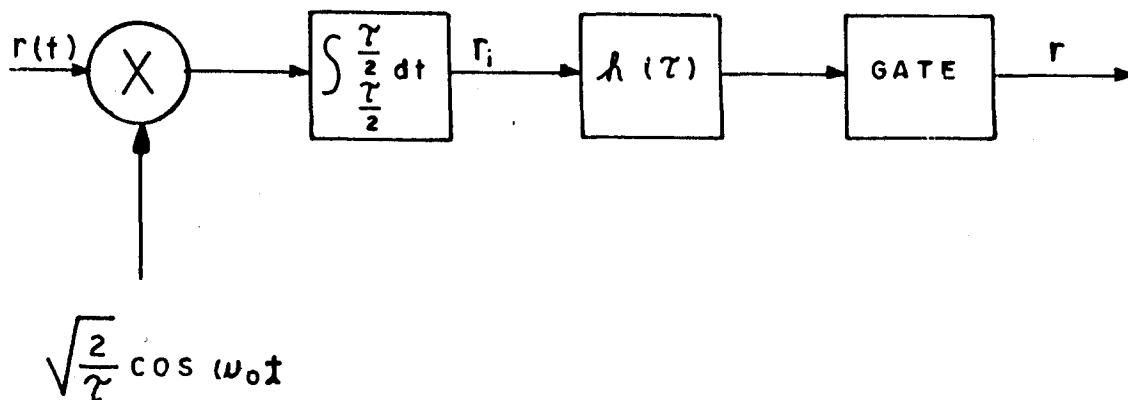


Figure 2. "I Only" Receive Channel

The canceller output of each frequency diverse channel has identical probability density function and is independent of any other channel. Two different interpulse periods are each shared by each group of two frequency diverse channels.

The channel shown in Figure 2 is the basic coherent correlator followed by a gated MTI three-pulse canceller. The output variable, r , may be combined with the output variables, r_i , of other channels in several ways, each giving different levels of performance as will be shown later. Four different configurations for combining the variables, r , are shown in Figures 3-A through 3-D.

Figures 3-A and 3-B show "I Only" processing of two frequency independent MTI channels, 3-A representing envelope detection and 3-B representing square law detection of the Gaussian variables, r , from the output of the three-pulse canceller. Each configuration represents six received pulses, three for I_1 and three for I_2 , respectively, at a particular interpulse interval, T_A .

Figures 3-C and 3-D show I and Q processing of the two frequency independent MTI channels in the same manner as in Figures 3-A and 3-B.

After applying the test statistics, ℓ_A , to a threshold and thereafter to a scope, a second statistic, ℓ_E , processed in an identical fashion from two other MTI channels having different independent frequencies and a different interpulse interval, T_E , is also thresholded 0.5 seconds later. This second statistic accounts for six more received pulses so that a total of twelve pulses are processed before the sequence repeats itself. A target at beam center will be indicated at the scope if either ℓ_A or ℓ_E or both are above the threshold. (See Figure 4.)

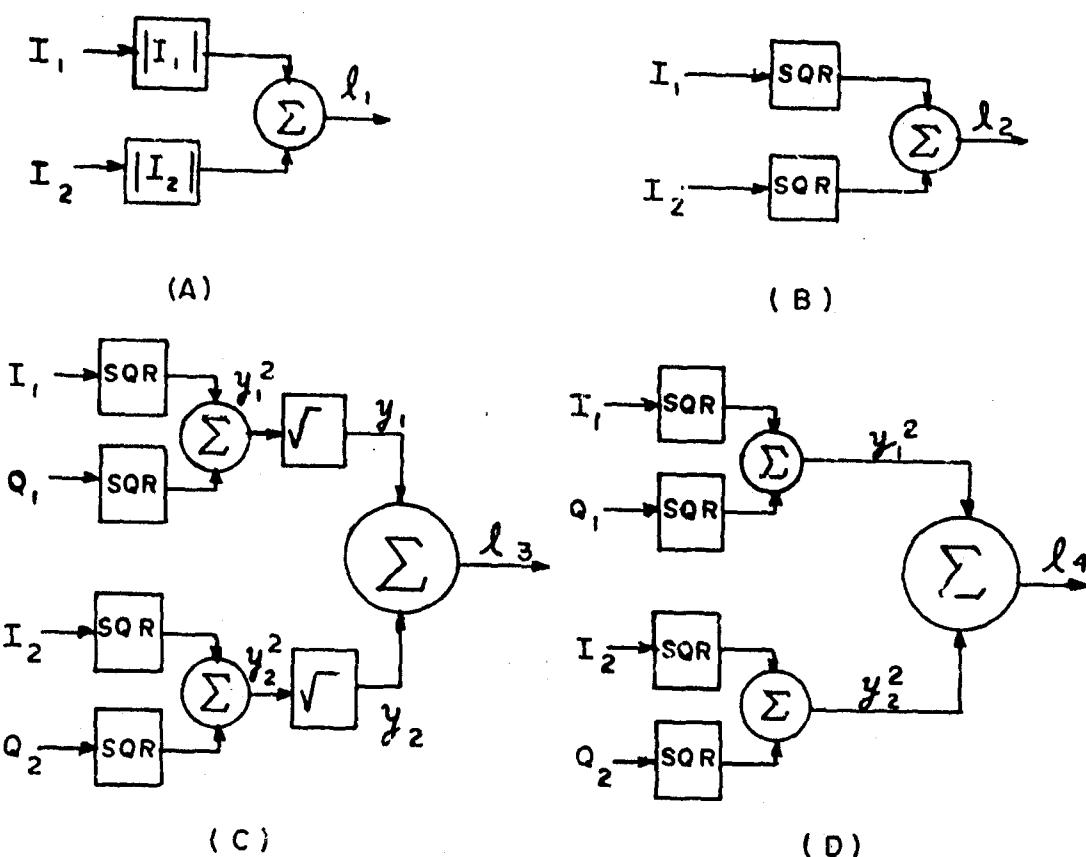


Figure 3. Four Receiver Models

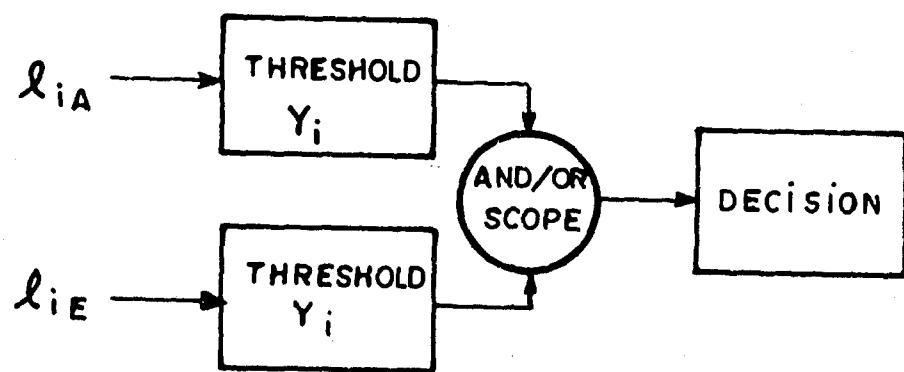


Figure 4. Combination Of Dual Channels

Figure 4. Combination of Dual Channels

DERIVATION OF SIGNAL-TO-NOISE FOR GIVEN PROBABILITY OF DETECTION

Let us start the derivation with the probability density function of the gated output from the canceller, equation 5. After performing the transformations appropriate for the block diagrams of Figure 3, we have the probability density function of ℓ_i , (the details of this analysis are found in Appendix B) is

$$P_{\ell_1 | \omega_d, H_1} (\ell_1 | \Omega_d, H_1) = \frac{2}{\sqrt{\pi} \sigma_1} \exp \left\{ -\frac{\ell_1^2}{4\sigma_1^2} \right\} [1 - \operatorname{erfc} \left\{ \frac{\ell_1}{2\sigma_1} \right\}] \quad (7-A)$$

$$P_{\ell_2 | \omega_d, H_1} (\ell_2 | \Omega_d, H_1) = \frac{1}{2\sigma_1^2} \exp \left\{ -\frac{\ell_2^2}{2\sigma_1^2} \right\} \quad (7-B)$$

$$P_{\ell_3 | \omega_d, H_1} (\ell_3 | \Omega_d, H_1) = \frac{\ell_3}{2\sigma_1^2} \exp \left\{ -\frac{\ell_3^2}{2\sigma_1^2} \right\} + \frac{\sqrt{\pi}}{2\sigma_1} \exp \left\{ -\frac{\ell_3^2}{4\sigma_1^2} \right\}$$

$$\left(\frac{\ell_3^2}{2\sigma_1^2} - 1 \right) \operatorname{erf} \left\{ \frac{\ell_3}{2\sigma_1} \right\} \quad (7-C)$$

$$P_{\ell_4 | \omega_d, H_1} (\ell_4 | \Omega_d, H_1) = \frac{\ell_4}{4\sigma_1^4} \exp \left\{ -\frac{\ell_4^2}{2\sigma_1^2} \right\} \quad (7-D)$$

with signal present. When the signal is not present

$$P_{\ell_i | H_0} (\ell_i | H_0) = P_{\ell_i | \omega_d, H_1} (\ell_i | \Omega_d, H_1) \quad \Bigg| \quad \sigma_1 = \sigma_0 \quad (8)$$

Equation (8) was written in this form to save space since it is identical to Equation (7) except that σ_0 is substituted for σ_1 .

As is well known the probability of false alarm is derived [1] by the following

$$P_{F_i} = \int_{\gamma_i}^{\infty} P_{\ell_i | H_0} (\ell_i | H_0) d\ell_i \quad (9)$$

EXAMPLE: THRESHOLD COMPUTATION:

For each of the four cases we set $P_{F_A, E}$ equal to 5×10^{-7} in order to obtain a false alarm probability at the scope of 10^{-6} . From Figure 4 we see that at the scope

$$P_F = P_{F_A} + P_{F_E} \cdot P_{F_A} \cdot P_{F_E} \cong 2P_{F_A} \quad (10)$$

when

$$0 < P_{F_A} = P_{F_E} < < 1$$

Evaluating the integral in (9) for each of the four cases, substituting for σ_0 , and setting the P_{F_i} equal to 5×10^{-7} , for example, we have

$$2 \operatorname{erfc} \left\{ \frac{\gamma_1}{2\sqrt{3N_0}} \right\} \cong 5 \times 10^{-7} \quad (11-A)$$

$$\exp \left\{ -\frac{\gamma_2}{6N_0} \right\} = 5 \times 10^{-7} \quad (11-B)$$

$$\exp \left\{ -\frac{\gamma_3^2}{12N_0} \right\} [\sqrt{\pi} \frac{\gamma_3}{2\sqrt{3N_0}} \operatorname{erf} \left\{ \frac{\gamma_3}{2\sqrt{3N_0}} \right\} + \exp \left\{ -\frac{\gamma_3^2}{12N_0} \right\}] = 5 \times 10^{-7} \quad (11-C)$$

$$\left(\frac{\gamma_4}{6N_0} + 1 \right) \exp \left\{ -\frac{\gamma_4}{6N_0} \right\} = 5 \times 10^{-7} \quad (11-D)$$

Solving for the various thresholds γ_i we have

$$\gamma_1 = 7.30 \sqrt{3N_0} \quad (12-A)$$

$$\gamma_2 = 29 \times 3N_0 \quad (12-B)$$

$$\gamma_3 = 8.1 \sqrt{3N_0} \quad (12-C)$$

$$\gamma_4 = 35 \times 3N_0 \quad (12-D)$$

Returning to our discussion we may use these threshold values and the probability density function of Equation (7) to evaluate the probability of detection of each of the models in Figure 3 through the integral.

$$P_i(\ell_{iA} > \gamma_i | \omega_d, H_1) = \int_{\gamma_i}^{\infty} P_{\ell_{iA} | \omega_d, H_1}(\ell_{iA} | \Omega_d, H_1) d\ell_{iA} \quad (13)$$

where the subscript A denotes the particular choice of interpulse period T_A or T_E of which the variance σ_1^2 is a function.

Evaluating this integral for each one of the cases in Figure 3 we have

$$P_1(\ell_{1A} > \gamma_1 | \omega_d, H_1) = 1 - \operatorname{erf}^2 \left\{ \frac{\gamma_1}{2\sigma_1} \right\} \quad (14-A)$$

$$P_2(\ell_{2A} > \gamma_2 | \omega_d, H_1) = \exp \left\{ -\frac{\gamma_2}{2\sigma_1^2} \right\} \quad (14-B)$$

$$P_3(\ell_{3A} > \gamma_3 | \omega_d, H_1) = \exp \left\{ -\frac{\gamma_3^2}{4\sigma_1^2} \right\} [\sqrt{\pi} \frac{\gamma_3}{2\sigma_1} \operatorname{erf} \left\{ \frac{\gamma_3}{2\sigma_1} \right\} + \exp \left\{ -\frac{\gamma_3^2}{4\sigma_1^2} \right\}] \quad (14-C)$$

$$P_4(\ell_{4A} > \gamma_4 | \omega_d, H_1) = \left(\frac{\gamma_4}{2\sigma_1^2} + 1 \right) \exp \left\{ -\frac{\gamma_4}{2\sigma_1^2} \right\} \quad (14-D)$$

Equation (14) is the probability that the signal, derived from the six received pulses of period T_A and present at the output of the network shown in Figure 3 (or the input to the A port of Figure 4), exceeds the threshold for a particular target radial velocity associated with ω_d . When the six pulses having period T_E are also applied to the and/or circuit of Figure 4 the overall probability of detection for all twelve pulses and for a particular ω_d is

$$P_{D_i} | \omega_d = P_i ([\ell_{iA} > \gamma_i] \cup [\ell_{iE} > \gamma_i] | \omega_d, H_1) \quad (15)$$

$$= P_i(\ell_{iA} > \gamma_i | \omega_d, H_1) + P_i(\ell_{iE} > \gamma_i | \omega_d, H_1) \cdot P_i([\ell_{iA} > \gamma_i] \cap [\ell_{iE} > \gamma_i] | \omega_d, H_1)$$

Since the events $\ell_{iA} > \gamma_i$ and $\ell_{iE} > \gamma_i$ are independent the last term in (15) can be written as the product of their probabilities.

The average detection probability may be computed by integrating out the dependency on ω_d

$$P_{D_i} = \int_{\Omega_d} P_i([\ell_{iA} > \gamma_i] \cup [\ell_{iE} > \gamma_i] | \omega_d, H_1) P_{\omega_d} | H_1 (\omega_d | H_1) d\omega_d \quad (16)$$

Where $P_{\omega_d} | H_1 (\omega_d | H_1)$ is the probability density function of the doppler frequency ω_d and integration is over the range of ω_d .

COMPOSITE DETECTION PROBABILITY OVER POSITION AND VELOCITY

Thus far we have derived the expressions for the conditional probability of detection when the target is located in the center of beam A and E. In this special case, beam E is spatially coincident with A but occurs one-half second later. The detection probability given in Equation (15) is conditional on target velocity and beam center. The detection probability of Equation (16) is composite over target velocity and is conditional only on beam center. These expressions may be applied to any receiver case of Figure 3 by assigning the appropriate index, i , to the subscripts in Equation (15) and (16) and making the proper substitution from Equation (14).

We shall now make the detection problem even more conditional by introducing multiple antenna beams, each having its own position L along with its own PRF, T_L . We also may assume that the target is located at a common but random position, ϕ , within the beams' coverage. Now defining a detection as constituting a hit in one or more of K beams we have for the conditional detection probability of a particular receiver case

$$\begin{aligned} P[(\ell_A > \gamma) \cup (\ell_B > \gamma) \cup \dots (\ell_{LK} > \gamma) | \phi, \omega_d, H_1] = \\ 1 - [1 - P(\ell_A > \gamma | \phi, \omega_d, H_1)] [1 - P(\ell_B > \gamma | \phi, \omega_d, H_1)] \dots [1 - P(\ell_{LK} > \gamma | \phi, \omega_d, H_1)] \end{aligned} \quad (17)$$

That is, a detection is made if the target is detected in beam A or beam B or . . . beam LK, or any combination thereof.

The subscript "i" for the receiver case has been omitted. It is assumed that the signal and noise received from each beam A, B, C, . . . LK is uncorrelated and therefore independent.

The composite probability of detection for all K beam positions is therefore obtained by averaging Equation (17) with respect to ϕ and ω_d .

$$P_D \Big| \text{K Beams} = \int_{\phi} \int_{\Omega} P[(\ell_A > \gamma) \cup (\ell_B > \gamma) \cup \dots (\ell_{LK} > \gamma) | \phi, \omega_d | H_1] P(\phi, \omega_d | H_1) d\phi d\omega_d \quad (18)$$

Since the target position, ϕ , within the beams is independent of velocity, ω_d , we may write

$$P(\phi, \omega_d | H_1) = P(\phi | H_1) P(\omega_d | H_1).$$

Equation (18) is the average probability of detection for the coherent MTI mode. The averaging is over the spatial coverage and over the target velocity. This equation also considers a detection when the processed signal crosses the threshold in beam A or beam B or . . . beam LK, or any combination thereof.

COMPUTER RESULTS

The expressions given above were programmed on the computer. The program was written to accommodate any number of beams A, B, C . . . LK each of which may have assigned a particular PRF interval, $T_A, T_B, T_C \dots T_{LK}$. An example of four beams and their relative locations is shown in Figure 1 (provided by the contractor). A triangle of symmetry by which the entire coverage can be represented is also shown. The target is assumed to be located anywhere within this triangle (and therefore anywhere within the coverage) with uniform probability. To facilitate the computation, the target location was given a uniform discrete probability density function at ten equally spaced points within the triangle.

$$P(\phi | H_1) = \frac{1}{10} \sum_{j=1}^{10} \delta(\phi - \phi_j) \quad (19)$$

For the same reason the velocity is also assumed to have a uniform discrete distribution

$$P(\omega_d | H_1) = \frac{1}{10} \sum_{l=1}^{10} \delta(\omega_d - \omega_{dl}) \quad (20)$$

Each of the density functions on the right side of Equation (17) are evaluated first giving

Beam A:

$$P(\ell_A > \gamma | \phi, \omega_{dl}, H_1) = \\ P(\ell > \gamma | \omega_{dl}, H_1) \left| \begin{array}{l} T = T_A \\ \sigma_s^2 / A = 10 \cdot \frac{GA(j)}{10} \sigma_s^2 \end{array} \right. = P_{D/A}$$

Beam B:

$$P(\ell_B > \gamma | \phi_j, \omega_{dl}, H_1) = \\ P(\ell > \gamma | \omega_{dl}, H_1) \left| \begin{array}{l} T = T_B \\ \sigma_s^2 / B = 10 \cdot \frac{GB(j)}{10} \sigma_s^2 \end{array} \right. = P_{D/B}$$

Beam L:

$$P(\ell_L > \gamma | \phi_j, \omega_{dl}, H_1) = \\ P(\ell > \gamma | \omega_{dl}, H_1) \left| \begin{array}{l} T = T_L \\ \sigma_s^2 / L = 10 \cdot \frac{GL(j)}{10} \sigma_s^2 \end{array} \right. = P_{D/L} \quad (21)$$

The middle part of equation (21) is taken from Equation (14) where $\sigma_s^2 j A$, the target amplitude, is substituted for σ_s^2 in the definition for σ_1^2 , following Equation (6-B). $GA(j)$ is the two-way antenna gain (beam center gain equals unity) for the A beam target located at the j point in the triangular coverage sector. Values used for $GL(j)$ were provided by the contractor, Raytheon, and are shown listed in Table I.

From Equation (21) one can see that for each value of $P_{Dij} Lk$ the variance under H_1 , σ_1^2 , (as defined under equation (6) and appearing in equation (14) for detection probability) is dependent on *beam position, PRF, Target location, and velocity*. *Beam Position* and *PRF* dependence is lumped together through Equation (17) which is repeated here in modified form.

$$P_{Dij} (\text{All K Beams}) = 1 - (1 - P_{Dij} A)(1 - P_{Dij} B) \dots (1 - P_{Dij} LK) \quad (22)$$

Target Location is averaged out by performing the integration indicated in Equation (18) with respect to ϕ .

$$P_{Di} (\text{K Beams}) = \frac{1}{10} \sum_{=1}^{10} P_{Dij} (\text{K Beams}) \quad (23)$$

Finally, *Velocity Dependence* is averaged out by a similar integration on P_{Di} .

$$P_D (\text{K Beams}) = \frac{1}{10} \sum P_{Di} (\text{K Beams}) \quad (24)$$

The values used for the antenna beam -- target location two-way gain, $GL(j)$, are given in Table I for the four beams shown in Figure 1. The values for target velocity used to compute the doppler frequency, ω_{di} , range from 105 knots to 195 knots in 10 knot intervals. This is considered a typical velocity range for a landing radar and spans at least one spectral PRF interval. Therefore, averaging over a larger velocity range would give the same result.

Tables VII through XVI give the probability of detection, Equation (23), for different values of target signal-to-noise ratios (referenced to target on beam center) and at different target velocities. Also given is the detection probability averaged over velocity, Equation (24). False alarm probability is 10^{-5} . Two PRFs were assumed and are indicated by T_1 and T_2 . The beam-target location characteristics used are as follows for each designated beam.

BEAM	TWO-WAY GAIN	PRF
A	$GA(j)$	T_1
B	$GB(j)$	T_2
C	$GC(j)$	T_2
D	$GD(j)$	T_1
E	$GA(j)$	T_3
F	$GB(j)$	T_1
G	$GC(j)$	T_1
H	$GD(j)$	T_2

As indicated Tables VII through XVI include detection over the two, four, and eight strongest beams. They also include all four receiver cases analyzed with the following respective thresholds for a probability of false alarm of 10^{-5} per beam position

$$\gamma_1 = 6.46 \sqrt{3N_0}$$

$$\gamma_2 = 23.0 \times 3N_0$$

$$\gamma_3 = 7.32 \sqrt{3N_0}$$

$$\gamma_4 = 28.4 \times 3N_0$$

The values for ω_{di} corresponding to target radial velocities between 100 and 200 knots were obtained from the relation

$$\omega_{di} = 4\pi v f_0 / C$$

$$= 194 v_k$$

where v is target velocity, C is the velocity of light, f_0 is the carrier frequency, 9.01 GHz and v_k is target velocity in knots (nautical miles per hour).

Since the storage time of the scope is not known, the analysis was not carried out for more than 1 second, i.e., one complete round of looks, 2 scans.

Tables XVII through XX give the probability of detection for the target located at the center of beams A and B. The other beams are not considered for off-center performance in computing the data in Tables XVII through XX.

Tables XIX and XX are presented in a different format than the preceding tables. At the top of each group of data a signal-to-noise ratio is given as a direct power ratio (not in dB) followed by the receiver case being considered. The false alarm probability which appears on each page of data is the overall value for the two beams A & B, i.e., for one beam P_f is 5×10^{-7} . The first column of values represent the target velocity in knots; the second and third column of values denote the detection probabilities in Beam A and Beam B, respectively, Equation (14); the fourth column denotes probability in either of the two beams, Equation (15); and the average probability at the bottom of each group of data denotes averaging only over velocity, Equation (16).

As expected, for I and Q processing a marked improvement is obtained as compared for I processing only with all probabilities of detection analyzed. The improvement is brought about by integration gain and diversity gain when going from the independent channels of "I Only" to twice as many independent channels of I and Q each. The improvement in the required signal-to-noise ratio for the particular average detection probability can be seen by comparing case 1 or 2 with case 3 or 4 of the tables. This is in general agreement with the literature [3, 4] for video integration of the two independent pulses versus video integration of four independent pulses. (Note that one video detected pulse must consist of two independent Gaussian components.)

As expected [5] the tables also show a slight improvement for square law detection, 2 and 4, compared to envelope detection, 1 and 3.

CONCLUSIONS

Tables XXI and XXII summarize the results of this analysis.

The values of S/N for a single beam center (unity weighting) obtained by Ward [6] using Barton [7] differed slightly from those obtained using Appendix A of this report. This difference is maintained after averaging the detection probability over all ten points of the coverage triangle in Beam A and/or Beam B. These values are shown in Table XXI.

In Table XXII it can be seen that failure to average the detection probability over velocity or beam coverage results in optimistic values for signal-to-noise ratio. For example, there is approximately a 4.0 dB difference between the MTI values obtained by Ward using an average velocity and those computed herein for Beams A and/or B, (AUB) (A union B). There is also a difference of about 2.0 dB in signal-to-noise ratio for beams AUE, on center as compared to target position averaging but in this case a similar difference is realized in the scan mode and so the MTI loss is unchanged.

The last set of conditions in Table XXII represent the most likely situation. Here the target is observed in two of the beams (AUB) during the first scan and again (EUF) during the second scan. Probability of detection has been averaged over beam coverage and over velocity. The MTI loss for false alarm probability of 10^{-5} per beam and overall detection probability of 75% is 8.0 dB for I^2 only MTI and 4.9 dB for $I^2 + Q^2$ MTI.

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TABLE I
ANTENNA BEAM -- TARGET LOCATION TWO WAY GAIN (DB)

GA(1)=.08	GB(1)=10.66	GC(1)=10.80	GD(1)=21.00
GA(2)=00.74	GB(2)= 8.26	GC(2)= 8.40	GD(2)=16.00
GA(3)= 2.40	GB(3)= 6.90	GC(3)= 6.80	GD(3)=11.30
GA(4)= 4.66	GB(4)= 6.02	GC(4)= 6.00	GD(4)= 7.20
GA(5)= 0.46	GB(5)= 7.94	GC(5)=11.00	GD(5)=18.40
GA(6)= 1.62	GB(6)= 6.12	GC(6)= 9.20	GD(6)=13.50
GA(7)= 3.46	GB(7)= 4.96	GC(7)= 8.00	GD(7)= 9.50
GA(8)= 1.20	GB(8)= 4.78	GC(8)=11.80	GD(8)=16.40
GA(9)= 2.70	GB(9)= 4.24	GC(9)=10.10	GD(9)=11.80
GA(10)= 2.30	GB(10)= 3.84	GC(10)=12.80	GD(10)=14.40

TABLE II
DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

$N = 3$ $M = 2$

False Alarm Probability

<u>S/N RATIO</u>	<u>10^{-3}</u>	<u>10^{-4}</u>	<u>10^{-5}</u>	<u>10^{-6}</u>	<u>10^{-7}</u>
2.10	16.45	19.55	22.53	25.41	28.22
2.20	0.2208	0.1331	0.0810	0.0499	0.0310
2.30	0.2282	0.1390	0.0854	0.0531	0.0333
2.40	0.2358	0.1450	0.0900	0.0565	0.0358
2.50	0.2435	0.1513	0.0948	0.0600	0.0383
2.60	0.2514	0.1577	0.0997	0.0637	0.0410
2.70	0.2593	0.1642	0.1048	0.0676	0.0439
2.80	0.2674	0.1710	0.1101	0.0716	0.0469
2.90	0.2757	0.1779	0.1156	0.0758	0.0501
3.00	0.2840	0.1849	0.1212	0.0802	0.0534
3.10	0.2925	0.1922	0.1270	0.0847	0.0569
3.20	0.3010	0.1996	0.1331	0.0895	0.0606
3.30	0.3097	0.2071	0.1393	0.0944	0.0644
3.40	0.3185	0.2148	0.1456	0.0995	0.0684
3.50	0.3274	0.2227	0.1522	0.1048	0.0726
3.60	0.3363	0.2307	0.1589	0.1103	0.0770
3.70	0.3454	0.2389	0.1659	0.1160	0.0816
3.80	0.3545	0.2472	0.1730	0.1218	0.0863
3.90	0.3637	0.2556	0.1802	0.1279	0.0912
4.00	0.3730	0.2642	0.1877	0.1341	0.0964
4.10	0.3823	0.2729	0.1953	0.1406	0.1017
4.20	0.3917	0.2817	0.2031	0.1472	0.1072
4.30	0.4011	0.2906	0.2110	0.1540	0.1129
4.40	0.4106	0.2997	0.2191	0.1610	0.1188
4.50	0.4201	0.3088	0.2274	0.1682	0.1249
4.60	0.4296	0.3181	0.2358	0.1756	0.1312
4.70	0.4392	0.3274	0.2444	0.1831	0.1377
4.80	0.4488	0.3369	0.2531	0.1909	0.1444
4.90	0.4584	0.3464	0.2619	0.1988	0.1513
5.00	0.4680	0.3560	0.2709	0.2068	0.1584
5.10	0.4776	0.3656	0.2800	0.2151	0.1656
5.20	0.4872	0.3754	0.2892	0.2235	0.1731
5.30	0.4968	0.3852	0.2985	0.2320	0.1807
5.40	0.5064	0.3950	0.3080	0.2407	0.1886
5.50	0.5159	0.4049	0.3175	0.2496	0.1966
5.60	0.5254	0.4148	0.3272	0.2586	0.2047
5.70	0.5349	0.4247	0.3369	0.2677	0.2131
5.80	0.5444	0.4347	0.3467	0.2770	0.2216
5.90	0.5538	0.4447	0.3566	0.2863	0.2303
	0.5631	0.4547	0.3665	0.2958	0.2391

TABLE II (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3, M = 2

False Alarm Probability

S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
6.00	0.5724	0.4647	0.3766	0.3055	0.2481
6.10	0.5816	0.4746	0.3866	0.3152	0.2572
6.20	0.5908	0.4846	0.3967	0.3250	0.2665
6.30	0.5999	0.4946	0.4069	0.3349	0.2758
6.40	0.6089	0.5045	0.4171	0.3449	0.2854
6.50	0.6178	0.5144	0.4273	0.3549	0.2950
6.60	0.6266	0.5242	0.4375	0.3651	0.3047
6.70	0.6354	0.5341	0.4477	0.3753	0.3146
6.80	0.6441	0.5438	0.4579	0.3855	0.3246
6.90	0.6526	0.5535	0.4681	0.3958	0.3346
7.00	0.6611	0.5632	0.4784	0.4061	0.3447
7.10	0.6694	0.5728	0.4885	0.4165	0.3549
7.20	0.6777	0.5823	0.4987	0.4268	0.3652
7.30	0.6858	0.5917	0.5088	0.4372	0.3755
7.40	0.6939	0.6010	0.5189	0.4476	0.3859
7.50	0.7018	0.6103	0.5290	0.4580	0.3963
7.60	0.7096	0.6195	0.5390	0.4684	0.4067
7.70	0.7172	0.6285	0.5489	0.4787	0.4172
7.80	0.7248	0.6375	0.5588	0.4891	0.4277
7.90	0.7322	0.6464	0.5686	0.4994	0.4382
8.00	0.7395	0.6551	0.5783	0.5097	0.4487
8.10	0.7467	0.6638	0.5879	0.5199	0.4592
8.20	0.7538	0.6723	0.5975	0.5301	0.4697
8.30	0.7607	0.6807	0.6069	0.5402	0.4802
8.40	0.7675	0.6890	0.6163	0.5502	0.4907
8.50	0.7741	0.6972	0.6255	0.5602	0.5011
8.60	0.7807	0.7053	0.6347	0.5701	0.5114
8.70	0.7871	0.7132	0.6437	0.5800	0.5218
8.80	0.7933	0.7210	0.6527	0.5897	0.5320
8.90	0.7995	0.7286	0.6615	0.5993	0.5422
9.00	0.8055	0.7361	0.6702	0.6089	0.5524
9.10	0.8114	0.7435	0.6788	0.6183	0.5624
9.20	0.8171	0.7508	0.6872	0.6277	0.5724
9.30	0.8227	0.7579	0.6955	0.6369	0.5823
9.40	0.8282	0.7649	0.7037	0.6460	0.5921
9.50	0.8336	0.7717	0.7118	0.6550	0.6018
9.60	0.8388	0.7784	0.7197	0.6639	0.6114
9.70	0.8439	0.7850	0.7275	0.6727	0.6209
9.80	0.8489	0.7914	0.7351	0.6813	0.6303
9.90	0.8538	0.7977	0.7426	0.6898	0.6396

TABLE II (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3 M = 2

False Alarm Probability

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
10.00	0.8565	0.8039	0.7500	0.6981	0.6487
10.10	0.8631	0.8099	0.7572	0.7064	0.6578
10.20	0.8676	0.8158	0.7643	0.7144	0.6667
10.30	0.8720	0.8215	0.7712	0.7224	0.6755
10.40	0.8762	0.8271	0.7780	0.7302	0.6841
10.50	0.8804	0.8326	0.7847	0.7379	0.6926
10.60	0.8844	0.8379	0.7912	0.7454	0.7010
10.70	0.8883	0.8431	0.7975	0.7527	0.7092
10.80	0.8921	0.8482	0.8038	0.7600	0.7173
10.90	0.8958	0.8531	0.8098	0.7671	0.7253
11.00	0.8994	0.8580	0.8158	0.7740	0.7331
11.10	0.9029	0.8629	0.8216	0.7808	0.7407
11.20	0.9063	0.8672	0.8272	0.7874	0.7482
11.30	0.9096	0.8717	0.8328	0.7939	0.7556
11.40	0.9128	0.8760	0.8381	0.8003	0.7628
11.50	0.9159	0.8802	0.8434	0.8065	0.7699
11.60	0.9189	0.8843	0.8485	0.8125	0.7768
11.70	0.9218	0.8882	0.8535	0.8184	0.7835
11.80	0.9246	0.8921	0.8583	0.8242	0.7902
11.90	0.9273	0.8958	0.8631	0.8299	0.7966
12.00	0.9300	0.8995	0.8676	0.8353	0.8030

TABLE III
DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and B

N = 3 M = 2

False Alarm Probability

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
2.10	16.45	19.55	22.53	25.41	28.22
2.20	0.2543	0.1468	0.0865	0.0521	0.0319
2.30	0.2631	0.1535	0.0913	0.0555	0.0343
2.40	0.2720	0.1604	0.0964	0.0591	0.0369
2.50	0.2811	0.1675	0.1016	0.0629	0.0396
2.60	0.2903	0.1748	0.1070	0.0668	0.0424
2.70	0.2997	0.1823	0.1127	0.0710	0.0454
2.80	0.3093	0.1900	0.1185	0.0753	0.0486
2.90	0.3190	0.1979	0.1246	0.0798	0.0519
3.00	0.3289	0.2061	0.1309	0.0846	0.0554
3.10	0.3389	0.2144	0.1374	0.0895	0.0591
3.20	0.3491	0.2230	0.1441	0.0947	0.0630
3.30	0.3594	0.2317	0.1511	0.1000	0.0671
3.40	0.3698	0.2407	0.1582	0.1056	0.0714
3.50	0.3803	0.2498	0.1656	0.1114	0.0759
3.60	0.3909	0.2592	0.1733	0.1174	0.0806
3.70	0.4017	0.2687	0.1811	0.1237	0.0855
3.80	0.4125	0.2784	0.1892	0.1302	0.0906
3.90	0.4234	0.2883	0.1975	0.1369	0.0959
4.00	0.4344	0.2983	0.2060	0.1438	0.1015
4.10	0.4454	0.3086	0.2147	0.1510	0.1072
4.20	0.4565	0.3190	0.2236	0.1584	0.1132
4.30	0.4677	0.3295	0.2328	0.1660	0.1195
4.40	0.4789	0.3402	0.2421	0.1739	0.1260
4.50	0.4901	0.3510	0.2517	0.1820	0.1327
4.60	0.5014	0.3620	0.2615	0.1903	0.1396
4.70	0.5127	0.3731	0.2714	0.1989	0.1468
4.80	0.5239	0.3843	0.2816	0.2076	0.1542
4.90	0.5352	0.3956	0.2919	0.2166	0.1619
5.00	0.5464	0.4070	0.3024	0.2259	0.1698
	0.5576	0.4184	0.3131	0.2353	0.1779

TABLE III (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Team Numbers A and B

$N = 3$ $M = 2$

S/N Ratio	False Alarm Probability				
	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
5.10	0.5688	0.4300	0.3239	0.2450	0.1863
5.20	0.5800	0.4416	0.3349	0.2548	0.1949
5.30	0.5910	0.4533	0.3460	0.2649	0.2037
5.40	0.6021	0.4650	0.3573	0.2752	0.2128
5.50	0.6130	0.4768	0.3687	0.2856	0.2221
5.60	0.6239	0.4886	0.3802	0.2963	0.2316
5.70	0.6346	0.5004	0.3918	0.3071	0.2414
5.80	0.6453	0.5122	0.4036	0.3181	0.2513
5.90	0.6558	0.5240	0.4154	0.3292	0.2615
6.00	0.6663	0.5358	0.4273	0.3405	0.2719
6.10	0.6766	0.5476	0.4392	0.3520	0.2824
6.20	0.6868	0.5593	0.4513	0.3635	0.2932
6.30	0.6968	0.5709	0.4633	0.3752	0.3041
6.40	0.7067	0.5825	0.4754	0.3871	0.3152
6.50	0.7165	0.5941	0.4875	0.3990	0.3265
6.60	0.7261	0.6055	0.4997	0.4110	0.3380
6.70	0.7355	0.6169	0.5118	0.4231	0.3495
6.80	0.7447	0.6281	0.5239	0.4353	0.3613
6.90	0.7538	0.6393	0.5360	0.4475	0.3731
7.00	0.7627	0.6503	0.5481	0.4598	0.3851
7.10	0.7714	0.6612	0.5601	0.4721	0.3971
7.20	0.7800	0.6720	0.5720	0.4844	0.4093
7.30	0.7883	0.6826	0.5839	0.4967	0.4215
7.40	0.7965	0.6930	0.5957	0.5091	0.4339
7.50	0.8044	0.7034	0.6074	0.5214	0.4462
7.60	0.8122	0.7135	0.6190	0.5337	0.4587
7.70	0.8198	0.7234	0.6305	0.5459	0.4711
7.80	0.8271	0.7332	0.6419	0.5582	0.4836
7.90	0.8343	0.7428	0.6531	0.5703	0.4961
8.00	0.8412	0.7522	0.6642	0.5824	0.5086
8.10	0.8480	0.7615	0.6751	0.5944	0.5210
8.20	0.8546	0.7705	0.6859	0.6063	0.5335
8.30	0.8609	0.7793	0.6966	0.6181	0.5459
8.40	0.8671	0.7879	0.7070	0.6297	0.5582
8.50	0.8731	0.7963	0.7173	0.6413	0.5705
8.60	0.8783	0.8045	0.7274	0.6527	0.5827
8.70	0.8844	0.8125	0.7373	0.6639	0.5948
8.80	0.8898	0.8202	0.7470	0.6750	0.6069
8.90	0.8950	0.8278	0.7565	0.6860	0.6188

TABLE III (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and B

N = 3 M = 2

False Alarm Probability

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
9.00	0.9000	0.8351	0.7658	0.6968	0.6306
9.10	0.9048	0.8422	0.7748	0.7073	0.6422
9.20	0.9095	0.8491	0.7837	0.7177	0.6537
9.30	0.9139	0.8558	0.7924	0.7280	0.6651
9.40	0.9182	0.8623	0.8008	0.7380	0.6763
9.50	0.9224	0.8686	0.8090	0.7478	0.6873
9.60	0.9263	0.8746	0.8170	0.7574	0.6981
9.70	0.9301	0.8805	0.8248	0.7668	0.7088
9.80	0.9338	0.8861	0.8323	0.7759	0.7193
9.90	0.9372	0.8916	0.8396	0.7849	0.7296
10.00	0.9406	0.8968	0.8467	0.7936	0.7396
10.10	0.9438	0.9019	0.8536	0.8021	0.7495
10.20	0.9468	0.9067	0.8602	0.8103	0.7591
10.30	0.9497	0.9114	0.8667	0.8184	0.7685
10.40	0.9525	0.9159	0.8729	0.8262	0.7777
10.50	0.9551	0.9202	0.8789	0.8338	0.7867
10.60	0.9576	0.9243	0.8847	0.8411	0.7955
10.70	0.9600	0.9283	0.8902	0.8482	0.8040
10.80	0.9623	0.9321	0.8956	0.8551	0.8123
10.90	0.9645	0.9357	0.9008	0.8618	0.8203
11.00	0.9666	0.9392	0.9057	0.8682	0.8281
11.10	0.9685	0.9425	0.9105	0.8745	0.8357
11.20	0.9704	0.9456	0.9151	0.8805	0.8430
11.30	0.9721	0.9486	0.9195	0.8862	0.8502
11.40	0.9738	0.9515	0.9237	0.8918	0.8570
11.50	0.9754	0.9542	0.9277	0.8972	0.8637
11.60	0.9769	0.9568	0.9316	0.9023	0.8701
11.70	0.9783	0.9593	0.9352	0.9073	0.8763
11.80	0.9796	0.9617	0.9388	0.9120	0.8823
11.90	0.9809	0.9639	0.9421	0.9166	0.8880
12.00	0.9821	0.9660	0.9453	0.9209	0.8936

TABLE IV

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A, B, E, and F

N = 3 M = 2

False Alarm Probability

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
1.6.45	19.55	22.53	25.41	28.22	
2.10	0.4371	0.2676	0.1630	0.1002	0.0622
2.20	0.4498	0.2787	0.1716	0.1065	0.0668
2.30	0.4626	0.2900	0.1805	0.1132	0.0716
2.40	0.4755	0.3016	0.1897	0.1201	0.0766
2.50	0.4885	0.3134	0.1992	0.1273	0.0820
2.60	0.5015	0.3254	0.2090	0.1348	0.0876
2.70	0.5146	0.3377	0.2190	0.1427	0.0934
2.80	0.5277	0.3501	0.2294	0.1508	0.0991
2.90	0.5408	0.3628	0.2401	0.1593	0.1063
3.00	0.5539	0.3757	0.2511	0.1681	0.1131
3.10	0.5670	0.3887	0.2623	0.1772	0.1202
3.20	0.5801	0.4019	0.2739	0.1866	0.1276
3.30	0.5931	0.4153	0.2857	0.1963	0.1354
3.40	0.6061	0.4288	0.2977	0.2064	0.1435
3.50	0.6190	0.4424	0.3100	0.2168	0.1519
3.60	0.6318	0.4561	0.3226	0.2274	0.1606
3.70	0.6445	0.4699	0.3354	0.2384	0.1697
3.80	0.6571	0.4838	0.3484	0.2497	0.1791
3.90	0.6696	0.4977	0.3616	0.2613	0.1888
4.00	0.6819	0.5117	0.3751	0.2732	0.1988
4.10	0.6940	0.5257	0.3887	0.2853	0.2092
4.20	0.7060	0.5397	0.4024	0.2977	0.2199
4.30	0.7177	0.5537	0.4163	0.3104	0.2309
4.40	0.7293	0.5676	0.4304	0.3233	0.2423
4.50	0.7407	0.5815	0.4446	0.3365	0.2539
4.60	0.7518	0.5953	0.4588	0.3499	0.2658
4.70	0.7627	0.6091	0.4732	0.3635	0.2781
4.80	0.7733	0.6227	0.4876	0.3773	0.2906
4.90	0.7837	0.6362	0.5020	0.3913	0.3033
5.00	0.7939	0.6496	0.5165	0.4054	0.3164

TABLE IV (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A, B, E, and F

N = 3 M = 2

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
5.10	0.8038	0.6628	0.5310	0.4197	0.3297
5.20	0.8134	0.6759	0.5455	0.4341	0.3432
5.30	0.8227	0.6887	0.5599	0.4487	0.3569
5.40	0.8317	0.7014	0.5743	0.4633	0.3709
5.50	0.8405	0.7138	0.5886	0.4780	0.3850
5.60	0.8490	0.7260	0.6029	0.4928	0.3994
5.70	0.8572	0.7380	0.6170	0.5076	0.4138
5.80	0.8651	0.7497	0.6310	0.5224	0.4284
5.90	0.8727	0.7612	0.6448	0.5372	0.4432
6.00	0.8800	0.7724	0.6585	0.5519	0.4580
6.10	0.8870	0.7833	0.6720	0.5667	0.4729
6.20	0.8937	0.7939	0.6853	0.5813	0.4879
6.30	0.9002	0.8042	0.6984	0.5959	0.5029
6.40	0.9063	0.8142	0.7112	0.6103	0.5179
6.50	0.9122	0.8239	0.7238	0.6247	0.5329
6.60	0.9178	0.8333	0.7362	0.6388	0.5479
6.70	0.9232	0.8424	0.7482	0.6529	0.5629
6.80	0.9283	0.8511	0.7600	0.6667	0.5778
6.90	0.9331	0.8595	0.7715	0.6803	0.5926
7.00	0.9377	0.8676	0.7827	0.6937	0.6072
7.10	0.9420	0.8754	0.7936	0.7069	0.6218
7.20	0.9461	0.8829	0.8042	0.7198	0.6362
7.30	0.9500	0.8901	0.8143	0.7324	0.6504
7.40	0.9536	0.8969	0.8244	0.7448	0.6645
7.50	0.9570	0.9034	0.8348	0.7569	0.6783
7.60	0.9603	0.9097	0.8432	0.7686	0.6919
7.70	0.9633	0.9156	0.8521	0.7801	0.7052
7.80	0.9661	0.9212	0.8607	0.7912	0.7183
7.90	0.9688	0.9266	0.8698	0.8021	0.7312

TABLE IV (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A, B, E, and F

N = 3 M = 2

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
8.00	0.9713	0.9317	0.8769	0.8125	0.7437
8.10	0.9736	0.9365	0.8844	0.8227	0.7560
8.20	0.9757	0.9410	0.8917	0.8325	0.7679
8.30	0.9778	0.9453	0.8986	0.8419	0.7795
8.40	0.9796	0.9493	0.9052	0.8510	0.7908
8.50	0.9814	0.9531	0.9114	0.8598	0.8017
8.60	0.9830	0.9567	0.9174	0.8682	0.8123
8.70	0.9845	0.9600	0.9231	0.8762	0.8226
8.80	0.9858	0.9631	0.9284	0.8839	0.8325
8.90	0.9871	0.9661	0.9335	0.8913	0.8421
9.00	0.9883	0.9688	0.9383	0.8983	0.8512
9.10	0.9893	0.9714	0.9428	0.9050	0.8601
9.20	0.9903	0.9737	0.9471	0.9114	0.8685
9.30	0.9912	0.9759	0.9511	0.9174	0.8767
9.40	0.9921	0.9780	0.9548	0.9231	0.8844
9.50	0.9928	0.9799	0.9583	0.9286	0.8918
9.60	0.9935	0.9816	0.9616	0.9337	0.8989
9.70	0.9942	0.9833	0.9647	0.9385	0.9056
9.80	0.9947	0.9848	0.9676	0.9431	0.9120
9.90	0.9953	0.9862	0.9703	0.9474	0.9181
10.00	0.9957	0.9874	0.9728	0.9514	0.9238
10.10	0.9962	0.9886	0.9751	0.9552	0.9293
10.20	0.9966	0.9897	0.9772	0.9587	0.9344
10.30	0.9969	0.9906	0.9791	0.9620	0.9393
10.40	0.9972	0.9915	0.9818	0.9651	0.9438
10.50	0.9975	0.9924	0.9827	0.9680	0.9481
10.60	0.9978	0.9931	0.9843	0.9707	0.9521
10.70	FY				

TABLE V
DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3 M = 2

Center (No Beam Averaging)

<u>S/N Ratio</u>	<u>False Alarm Probability</u>				
	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
2.10	16.45	19.55	22.53	25.41	28.22
2.20	0.3813	0.2646	0.1822	0.1252	0.0858
2.30	0.3914	0.2740	0.1904	0.1319	0.0911
2.40	0.4015	0.2835	0.1987	0.1389	0.0968
2.50	0.4116	0.2932	0.2073	0.1460	0.1026
2.60	0.4218	0.3030	0.2160	0.1535	0.1087
2.70	0.4320	0.3129	0.2249	0.1611	0.1151
2.80	0.4422	0.3220	0.2340	0.1689	0.1216
2.90	0.4525	0.3331	0.2433	0.1770	0.1284
3.00	0.4628	0.3433	0.2527	0.1853	0.1355
3.10	0.4730	0.3536	0.2623	0.1938	0.1428
3.20	0.4833	0.3641	0.2720	0.2025	0.1503
3.30	0.4936	0.3745	0.2819	0.2114	0.1580
3.40	0.5038	0.3851	0.2920	0.2205	0.1660
3.50	0.5140	0.3957	0.3021	0.2298	0.1742
3.60	0.5242	0.4063	0.3124	0.2393	0.1826
3.70	0.5343	0.4170	0.3228	0.2489	0.1912
3.80	0.5443	0.4277	0.3333	0.2587	0.2001
3.90	0.5544	0.4384	0.3439	0.2687	0.2091
4.00	0.5643	0.4491	0.3546	0.2788	0.2184
4.10	0.5742	0.4598	0.3654	0.2890	0.2278
4.20	0.5840	0.4706	0.3762	0.2994	0.2374
4.30	0.5937	0.4813	0.3871	0.3099	0.2472
4.40	0.6033	0.4919	0.3980	0.3205	0.2572
4.50	0.6129	0.5026	0.4090	0.3313	0.2674
4.60	0.6223	0.5132	0.4199	0.3421	0.2776
4.70	0.6316	0.5238	0.4310	0.3530	0.2881
4.80	0.6409	0.5343	0.4420	0.3640	0.2986
4.90	0.6500	0.5447	0.4530	0.3750	0.3093
5.00	0.6598	0.5551	0.4640	0.3861	0.3201
	0.6678	0.5653	0.4750	0.3973	0.3310

TABLE V (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3 M = 2

Center (No Beam Averaging)

S/N Ratio	False Alarm Probability				
	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
5.10	0.6766	0.5756	0.4860	0.4085	0.3429
5.20	0.6852	0.5857	0.4969	0.4197	0.3531
5.30	0.6937	0.5957	0.5078	0.4309	0.3643
5.40	0.7021	0.6056	0.5186	0.4421	0.3755
5.50	0.7103	0.6154	0.5294	0.4533	0.3868
5.60	0.7184	0.6251	0.5401	0.4646	0.3981
5.70	0.7263	0.6347	0.5507	0.4757	0.4094
5.80	0.7341	0.6441	0.5613	0.4869	0.4208
5.90	0.7418	0.6534	0.5717	0.4980	0.4322
6.00	0.7493	0.6626	0.5821	0.5090	0.4435
6.10	0.7566	0.6717	0.5923	0.5200	0.4549
6.20	0.7638	0.6806	0.6025	0.5310	0.4663
6.30	0.7709	0.6894	0.6123	0.5418	0.4776
6.40	0.7778	0.6980	0.6224	0.5526	0.4888
6.50	0.7846	0.7065	0.6322	0.5633	0.5001
6.60	0.7912	0.7148	0.6418	0.5738	0.5112
6.70	0.7977	0.7230	0.6513	0.5843	0.5223
6.80	0.8040	0.7310	0.6607	0.5947	0.5334
6.90	0.8102	0.7389	0.6699	0.6049	0.5443
7.00	0.8162	0.7466	0.6798	0.6150	0.5552
7.10	0.8221	0.7542	0.6880	0.6258	0.5659
7.20	0.8278	0.7616	0.6967	0.6349	0.5766
7.30	0.8334	0.7689	0.7054	0.6446	0.5871
7.40	0.8389	0.7760	0.7138	0.6542	0.5976
7.50	0.8442	0.7829	0.7222	0.6636	0.6079
7.60	0.8494	0.7897	0.7303	0.6729	0.6180
7.70	0.8544	0.7963	0.7383	0.6820	0.6281
7.80	0.8593	0.8028	0.7461	0.6910	0.6386
7.90	0.8641	0.8091	0.7538	0.6998	0.6478
8.00	0.8687	0.8152	0.7613	0.7085	0.6574

TABLE V (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3 M = 2

Center (No Beam Averaging)

False Alarm Probability

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
8.10	0.8732	0.8212	0.7687	0.7170	0.6668
8.20	0.8776	0.8271	0.7759	0.7253	0.6761
8.30	0.8819	0.8328	0.7829	0.7335	0.6853
8.40	0.8860	0.8384	0.7897	0.7415	0.6943
8.50	0.8900	0.8438	0.7964	0.7493	0.7031
8.60	0.8939	0.8490	0.8030	0.7570	0.7118
8.70	0.8977	0.8541	0.8093	0.7645	0.7203
8.80	0.9013	0.8591	0.8156	0.7718	0.7286
8.90	0.9049	0.8640	0.8216	0.7790	0.7367
9.00	0.9083	0.8687	0.8275	0.7860	0.7447
9.10	0.9116	0.8732	0.8333	0.7929	0.7525
9.20	0.9148	0.8777	0.8388	0.7995	0.7602
9.30	0.9180	0.8820	0.8443	0.8060	0.7677
9.40	0.9210	0.8861	0.8496	0.8124	0.7750
9.50	0.9239	0.8902	0.8547	0.8185	0.7821
9.60	0.9267	0.8941	0.8597	0.8246	0.7891
9.70	0.9295	0.8979	0.8646	0.8304	0.7959
9.80	0.9321	0.9016	0.8693	0.8361	0.8025
9.90	0.9347	0.9052	0.8739	0.8417	0.8090
10.00	0.9371	0.9086	0.8783	0.8471	0.8153
10.10	0.9395	0.9120	0.8827	0.8523	0.8214
10.20	0.9418	0.9152	0.8868	0.8574	0.8274
10.30	0.9440	0.9184	0.8909	0.8624	0.8332
10.40	0.9462	0.9214	0.8948	0.8672	0.8388
10.50	0.9483	0.9243	0.8986	0.8719	0.8443
10.60	0.9503	0.9272	0.9023	0.8764	0.8497
10.70	0.9522	0.9299	0.9059	0.8808	0.8549
10.80	0.9540	0.9326	0.9094	0.8851	0.8599
10.90	0.9558	0.9351	0.9127	0.8892	0.8648
11.00	0.9576	0.9376	0.9159	0.8932	0.8696
11.10	0.9592	0.9400	0.9191	0.8971	0.8742
11.20	0.9608	0.9423	0.9221	0.9008	0.8787
11.30	0.9624	0.9445	0.9250	0.9045	0.8830
11.40	0.9639	0.9467	0.9279	0.9080	0.8872
11.50	0.9653	0.9487	0.9306	0.9114	0.8913
11.60	0.9667	0.9507	0.9332	0.9147	0.8953
11.70	0.9680	0.9526	0.9358	0.9179	0.8991
11.80	0.9693	0.9543	0.9382	0.9210	0.9028
11.90	0.9705	0.9563	0.9406	0.9239	0.9064
12.00	0.9717	0.9580	0.9429	0.9268	0.9099

TABLE VI
DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and E

N = 3 M = 2

Center (No Beam Averaging)

S/N Ratio	False Alarm Probability				
	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
2.10	16.45	19.55	22.53	25.41	28.22
2.20	0.6172	0.4592	0.3313	0.2347	0.1641
2.30	0.6296	0.4729	0.3445	0.2464	0.1740
2.40	0.6417	0.4867	0.3580	0.2584	0.1842
2.50	0.6538	0.5004	0.3716	0.2708	0.1947
2.60	0.6657	0.5142	0.3853	0.2834	0.2056
2.70	0.6774	0.5279	0.3992	0.2962	0.2169
2.80	0.6889	0.5416	0.4132	0.3094	0.2285
2.90	0.7002	0.5552	0.4274	0.3227	0.2404
3.00	0.7114	0.5688	0.4415	0.3363	0.2526
3.10	0.7223	0.5822	0.4558	0.3501	0.2651
3.20	0.7330	0.5956	0.4701	0.3640	0.2780
3.30	0.7435	0.6088	0.4844	0.3781	0.2911
3.40	0.7538	0.6219	0.4987	0.3924	0.3044
3.50	0.7638	0.6349	0.5130	0.4068	0.3180
3.60	0.7736	0.6475	0.5272	0.4213	0.3319
3.70	0.7831	0.6601	0.5414	0.4358	0.3459
3.80	0.7924	0.6724	0.5555	0.4505	0.3601
3.90	0.8014	0.6846	0.5696	0.4651	0.3745
4.00	0.8102	0.6965	0.5835	0.4798	0.3891
4.10	0.8187	0.7082	0.5972	0.4945	0.4037
4.20	0.8269	0.7197	0.6108	0.5092	0.4155
4.30	0.8349	0.7309	0.6243	0.5238	0.4334
4.40	0.8427	0.7419	0.6376	0.5383	0.4483
4.50	0.8501	0.7526	0.6507	0.5528	0.4632
4.60	0.8573	0.7630	0.6635	0.5672	0.4782
4.70	0.8643	0.7732	0.6762	0.5814	0.4932
4.80	0.8710	0.7831	0.6886	0.5955	0.5081
4.90	0.8775	0.7927	0.7005	0.6094	0.5238
5.00	0.8837	0.8026	0.7127	0.6232	0.5378
5.10	0.8897	0.8111	0.7244	0.6367	0.5525

TABLE VI (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and E

N = 3 M = 2

Center (No Beam Averaging)

S/N Ratio	False Alarm Probability				
	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
5.10	0.8954	0.8198	0.7358	0.6501	0.5671
5.20	0.9009	0.8283	0.7469	0.6632	0.5815
5.30	0.9062	0.8365	0.7577	0.6761	0.5959
5.40	0.9112	0.8444	0.7683	0.6888	0.6100
5.50	0.9161	0.8521	0.7785	0.7012	0.6239
5.60	0.9207	0.8594	0.7885	0.7133	0.6377
5.70	0.9251	0.8665	0.7981	0.7251	0.6512
5.80	0.9293	0.8733	0.8075	0.7367	0.6645
5.90	0.9333	0.8799	0.8166	0.7480	0.6776
6.00	0.9371	0.8862	0.8253	0.7590	0.6904
6.10	0.9408	0.8922	0.8335	0.7696	0.7029
6.20	0.9442	0.8980	0.8420	0.7800	0.7151
6.30	0.9475	0.9035	0.8498	0.7901	0.7271
6.40	0.9506	0.9088	0.8574	0.7996	0.7387
6.50	0.9536	0.9139	0.8647	0.8093	0.7501
6.60	0.9564	0.9187	0.8717	0.8184	0.7611
6.70	0.9591	0.9233	0.8784	0.8272	0.7718
6.80	0.9616	0.9277	0.8849	0.8357	0.7823
6.90	0.9640	0.9318	0.8911	0.8439	0.7924
7.00	0.9662	0.9358	0.8970	0.8518	0.8021
7.10	0.9684	0.9396	0.9026	0.8594	0.8116
7.20	0.9704	0.9432	0.9080	0.8667	0.8207
7.30	0.9723	0.9466	0.9132	0.8737	0.8295
7.40	0.9740	0.9498	0.9181	0.8804	0.8380
7.50	0.9757	0.9529	0.9228	0.8868	0.8462
7.60	0.9773	0.9558	0.9273	0.8930	0.8541
7.70	0.9788	0.9585	0.9315	0.8989	0.8617
7.80	0.9802	0.9611	0.9356	0.9045	0.8690
7.90	0.9815	0.9636	0.9394	0.9099	0.8759
8.00	0.9828	0.9659	0.9430	0.9150	0.8826
8.10	0.9839	0.9680	0.9465	0.9199	0.8890

TABLE VI (Continued)
DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and E

N = 3 M = 2

Center (No Beam Averaging)

False Alarm Probability

<u>S/N Ratio</u>	<u>10⁻³</u>	<u>10⁻⁴</u>	<u>10⁻⁵</u>	<u>10⁻⁶</u>	<u>10⁻⁷</u>
8.20	0.9850	0.9701	0.9498	0.9246	0.8951
8.30	0.9860	0.9720	0.9529	0.9290	0.9010
8.40	0.9870	0.9739	0.9558	0.9332	0.9065
8.50	0.9879	0.9756	0.9586	0.9372	0.9118
8.60	0.9887	0.9772	0.9612	0.9410	0.9169
8.70	0.9895	0.9787	0.9636	0.9445	0.9217
8.80	0.9903	0.9802	0.9660	0.9479	0.9263
8.90	0.9909	0.9815	0.9682	0.9512	0.9307
9.00	0.9916	0.9827	0.9702	0.9542	0.9348
9.10	0.9922	0.9839	0.9722	0.9571	0.9388
9.20	0.9927	0.9850	0.9740	0.9598	0.9425
9.30	0.9933	0.9861	0.9758	0.9624	0.9468
9.40	0.9938	0.9870	0.9774	0.9648	0.9494
9.50	0.9942	0.9879	0.9789	0.9671	0.9525
9.60	0.9946	0.9888	0.9803	0.9692	0.9555
9.70	0.9950	0.9896	0.9817	0.9712	0.9583
9.80	0.9954	0.9903	0.9829	0.9731	0.9610
9.90	0.9957	0.9910	0.9841	0.9749	0.9635
10.00	0.9960	0.9917	0.9852	0.9766	0.9659
10.10	0.9963	0.9923	0.9862	0.9782	0.9681
10.20	0.9966	0.9928	0.9872	0.9797	0.9702
10.30	0.9969	0.9933	0.9881	0.9811	0.9722
10.40	0.9971	0.9938	0.9889	0.9824	0.9740
10.50	0.9973	0.9943	0.9897	0.9836	0.9758
10.60	0.9975	0.9947	0.9905	0.9847	0.9774
10.70	0.9977	0.9951	0.9911	0.9858	0.9789
10.80	0.9979	0.9955	0.9918	0.9868	0.9804
10.90	0.9980	0.9958	0.9924	0.9877	0.9817
11.00	0.9982	0.9961	0.9929	0.9886	0.9836
11.10	0.9983	0.9964	0.9935	0.9894	0.9842
11.20	0.9985	0.9967	0.9939	0.9902	0.9853
11.30	0.9986	0.9969	0.9944	0.9909	0.9863
11.40	0.9987	0.9972	0.9948	0.9915	0.9873
11.50	0.9988	0.9974	0.9952	0.9921	0.9882
11.60	0.9989	0.9976	0.9955	0.9927	0.9890
11.70	0.9990	0.9978	0.9959	0.9933	0.9898
11.80	0.9991	0.9979	0.9962	0.9938	0.9906
11.90	0.9991	0.9981	0.9965	0.9942	0.9912
12.00	0.9992	0.9982	0.9967	0.9946	0.9919

TABLE VII
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4010$

$T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE I

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.002	0.006	0.021	0.062
115.	0.000	0.001	0.004	0.012	0.036	0.088	0.178
125.	0.001	0.004	0.013	0.037	0.090	0.180	0.302
135.	0.001	0.003	0.018	0.031	0.078	0.161	0.279
145.	0.000	0.001	0.002	0.006	0.020	0.053	0.120
155.	0.000	0.000	0.000	0.001	0.005	0.018	0.051
165.	0.001	0.002	0.008	0.025	0.067	0.147	0.266
175.	0.004	0.013	0.040	0.098	0.196	0.328	0.475
185.	0.010	0.032	0.082	0.172	0.299	0.444	0.586
195.	0.014	0.042	0.101	0.202	0.340	0.496	0.647
AVE =	0.003	0.010	0.026	0.059	0.114	0.194	0.296
	14.	16.	18.	20.	22.	24.	
105.	0.153	0.303	0.492	0.675	0.816	0.906	
115.	0.298	0.438	0.579	0.706	0.818	0.888	
125.	0.441	0.577	0.696	0.790	0.859	0.907	
135.	0.416	0.554	0.676	0.775	0.848	0.900	
145.	0.223	0.356	0.502	0.644	0.766	0.861	
155.	0.124	0.250	0.419	0.609	0.756	0.866	
165.	0.409	0.553	0.680	0.780	0.853	0.903	
175.	0.613	0.728	0.815	0.878	0.920	0.949	
185.	0.767	0.801	0.871	0.920	0.953	0.974	
195.	0.775	0.870	0.931	0.966	0.984	0.993	
AVE =	0.416	0.543	0.666	0.773	0.857	0.915	

TABLE VII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4010$

$T_2 = 1/2545$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.002	0.008	0.027	0.079
115.	0.000	0.301	0.005	0.016	0.046	0.107	0.206
125.	0.001	0.005	0.017	0.047	0.110	0.211	0.341
135.	0.001	0.004	0.014	0.040	0.096	0.190	0.316
145.	0.000	0.001	0.002	0.008	0.025	0.067	0.144
155.	0.000	0.000	0.001	0.002	0.007	0.023	0.065
165.	0.001	0.003	0.010	0.032	0.083	0.175	0.305
175.	0.005	0.017	0.051	0.119	0.230	0.370	0.517
185.	0.014	0.041	0.101	0.203	0.339	0.487	0.625
195.	0.018	0.053	0.124	0.237	0.384	0.541	0.688
AVE =	0.004	0.013	0.032	0.071	0.133	0.220	0.329
	14.	16.	18.	20.	22.	24.	
105.	0.186	0.353	0.547	0.722	0.848	0.924	
115.	0.336	0.480	0.618	0.739	0.836	0.906	
125.	0.482	0.615	0.727	0.813	0.876	0.919	
135.	0.457	0.593	0.709	0.800	0.866	0.912	
145.	0.258	0.397	0.544	0.682	0.797	0.883	
155.	0.152	0.292	0.471	0.649	0.794	0.891	
165.	0.452	0.594	0.713	0.805	0.870	0.916	
175.	0.651	0.758	0.837	0.893	0.931	0.955	
185.	0.739	0.825	0.887	0.931	0.960	0.979	
195.	0.807	0.891	0.944	0.973	0.988	0.995	
AVE =	0.452	0.580	0.700	0.801	0.877	0.928	

TABLE VII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4010$

$T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.004	0.015	0.053	0.155
115.	0.001	0.002	0.009	0.032	0.091	0.207	0.372
125.	0.002	0.009	0.033	0.095	0.212	0.379	0.562
135.	0.002	0.007	0.027	0.080	0.187	0.347	0.530
145.	0.000	0.001	0.004	0.015	0.050	0.132	0.271
155.	0.000	0.000	0.001	0.003	0.013	0.045	0.128
165.	0.001	0.005	0.020	0.064	0.165	0.328	0.524
175.	0.010	0.034	0.101	0.231	0.415	0.609	0.771
185.	0.027	0.083	0.199	0.374	0.570	0.741	0.861
195.	0.036	0.105	0.238	0.426	0.626	0.794	0.905
AVE =	0.008	0.025	0.063	0.132	0.234	0.363	0.508
	14.	16.	18.	20.	22.	24.	
105.	0.349	0.595	0.805	0.928	0.979	0.995	
115.	0.556	0.722	0.847	0.928	0.972	0.991	
125.	0.724	0.843	0.919	0.961	0.982	0.992	
135.	0.698	0.825	0.908	0.956	0.980	0.991	
145.	0.449	0.632	0.786	0.895	0.958	0.986	
155.	0.288	0.511	0.730	0.883	0.960	0.989	
165.	0.704	0.837	0.918	0.962	0.983	0.993	
175.	0.879	0.942	0.973	0.988	0.995	0.998	
185.	0.932	0.969	0.987	0.995	0.998	1.000	
195.	0.964	0.989	0.997	0.999	1.000	1.000	
AVE =	0.654	0.787	0.887	0.950	0.981	0.993	

TABLE VII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE
 Beam Numbers A and B $T_1 = 1/4010$ $T_2 = 1/2645$
 $P_F = 10^{-5}$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.004	0.018	0.063	0.181
115.	0.001	0.003	0.011	0.038	0.106	0.232	0.405
125.	0.003	0.011	0.039	0.110	0.238	0.411	0.594
135.	0.002	0.009	0.032	0.093	0.211	0.379	0.563
145.	0.000	0.001	0.005	0.019	0.060	0.151	0.299
155.	0.000	0.000	0.001	0.004	0.015	0.054	0.149
165.	0.002	0.006	0.024	0.076	0.188	0.361	0.559
175.	0.012	0.041	0.118	0.259	0.450	0.643	0.795
185.	0.032	0.097	0.225	0.408	0.605	0.768	0.878
195.	0.043	0.122	0.267	0.462	0.660	0.819	0.920
AVE =	0.010	0.029	0.072	0.147	0.255	0.388	0.534
	14.	16.	18.	20.	22.	24.	
105.	0.389	0.638	0.835	0.941	0.983	0.996	
115.	0.589	0.748	0.866	0.939	0.977	0.993	
125.	0.750	0.861	0.929	0.967	0.985	0.994	
135.	0.725	0.845	0.920	0.962	0.983	0.993	
145.	0.483	0.663	0.810	0.910	0.965	0.989	
155.	0.323	0.551	0.764	0.903	0.968	0.991	
165.	0.733	0.856	0.929	0.968	0.986	0.994	
175.	0.894	0.950	0.978	0.990	0.996	0.998	
185.	0.942	0.974	0.990	0.996	0.999	1.000	
195.	0.971	0.991	0.998	1.000	1.000	1.000	
AVE =	0.680	0.808	0.902	0.958	0.984	0.995	

TABLE VIII
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/2645$

$T_2 = 1/4010$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.002	0.006	0.020	0.055	0.128
115.	0.004	0.012	0.037	0.092	0.187	0.318	0.464
125.	0.013	0.029	0.095	0.192	0.323	0.470	0.629
135.	0.010	0.032	0.082	0.172	0.298	0.444	0.585
145.	0.002	0.006	0.020	0.055	0.126	0.238	0.378
155.	0.000	0.000	0.000	0.001	0.005	0.016	0.047
165.	0.000	0.000	0.001	0.002	0.008	0.025	0.064
175.	0.000	0.001	0.004	0.013	0.039	0.093	0.183
185.	0.001	0.003	0.011	0.032	0.079	0.164	0.286
195.	0.002	0.007	0.023	0.068	0.165	0.323	0.515
AVE =	0.003	0.010	0.027	0.063	0.125	0.214	0.326
	14.	16.	18.	20.	22.	24.	
105.	0.246	0.402	0.571	0.724	0.840	0.916	
115.	0.604	0.721	0.810	0.875	0.919	0.949	
125.	0.725	0.813	0.876	0.919	0.948	0.967	
135.	0.796	0.799	0.867	0.913	0.944	0.964	
145.	0.524	0.655	0.761	0.840	0.896	0.935	
155.	0.117	0.241	0.410	0.594	0.752	0.865	
165.	0.138	0.248	0.383	0.523	0.650	0.755	
175.	0.307	0.446	0.582	0.699	0.792	0.861	
185.	0.405	0.592	0.734	0.844	0.918	0.960	
195.	0.696	0.831	0.915	0.960	0.982	0.992	
AVE =	0.450	0.575	0.691	0.789	0.864	0.916	

TABLE VIII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/2645$

$T_2 = 1/4010$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.008	0.025	0.069	0.154
115.	0.005	0.016	0.047	0.113	0.220	0.359	0.507
125.	0.017	0.049	0.116	0.225	0.365	0.513	0.646
135.	0.014	0.041	0.101	0.203	0.339	0.487	0.624
145.	0.002	0.008	0.026	0.069	0.152	0.275	0.421
155.	0.000	0.000	0.000	0.002	0.006	0.020	0.060
165.	0.000	0.000	0.001	0.003	0.010	0.031	0.080
175.	0.000	0.001	0.005	0.017	0.049	0.113	0.215
185.	0.001	0.004	0.014	0.040	0.097	0.193	0.326
195.	0.002	0.009	0.030	0.086	0.201	0.374	0.570
AVE =	0.004	0.013	0.034	0.077	0.146	0.243	0.360
	14.	16.	18.	20.	22.	24.	
105.	0.286	0.449	0.618	0.762	0.867	0.932	
115.	0.642	0.751	0.832	0.890	0.930	0.956	
125.	0.754	0.835	0.891	0.930	0.955	0.971	
135.	0.737	0.822	0.883	0.924	0.951	0.969	
145.	0.565	0.690	0.788	0.859	0.909	0.944	
155.	0.143	0.283	0.462	0.644	0.791	0.889	
165.	0.165	0.284	0.424	0.562	0.684	0.783	
175.	0.346	0.487	0.619	0.739	0.816	0.877	
185.	0.480	0.635	0.770	0.870	0.933	0.968	
195.	0.741	0.861	0.932	0.969	0.986	0.994	
AVE =	0.486	0.610	0.722	0.814	0.882	0.928	

TABLE VIII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/2645$ $T_2 = 1/4010$
 $P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.004	0.015	0.050	0.137	0.292
115.	0.009	0.032	0.094	0.219	0.400	0.596	0.761
125.	0.033	0.098	0.226	0.408	0.603	0.766	0.876
135.	0.027	0.082	0.198	0.373	0.570	0.741	0.860
145.	0.004	0.015	0.051	0.138	0.289	0.482	0.670
155.	0.000	0.000	0.001	0.003	0.011	0.040	0.118
165.	0.000	0.000	0.001	0.005	0.020	0.063	0.156
175.	0.001	0.002	0.010	0.034	0.098	0.217	0.385
185.	0.002	0.007	0.027	0.080	0.189	0.352	0.544
195.	0.004	0.016	0.059	0.170	0.373	0.622	0.825
AVE =	0.008	0.025	0.067	0.145	0.260	0.402	0.549
	14.	16.	18.	20.	22.	24.	
105.	0.498	0.704	0.859	0.946	0.983	0.996	
115.	0.873	0.938	0.972	0.988	0.995	0.998	
125.	0.940	0.973	0.988	0.995	0.998	0.999	
135.	0.931	0.969	0.986	0.994	0.998	0.999	
145.	0.813	0.905	0.955	0.980	0.992	0.997	
155.	0.274	0.497	0.722	0.880	0.959	0.989	
165.	0.306	0.487	0.661	0.880	0.893	0.948	
175.	0.568	0.729	0.847	0.921	0.962	0.983	
185.	0.727	0.866	0.948	0.983	0.996	0.999	
195.	0.937	0.982	0.996	0.999	1.000	1.000	
AVE =	0.687	0.805	0.893	0.949	0.978	0.991	

TABLE VIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

 $T_1 = 1/2645$ $T_2 = 1/4010$ $P_F = 10^{-5}$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.065	0.318	0.060	0.158	0.325
115.	0.011	0.038	0.110	0.247	0.435	0.630	0.786
125.	0.040	0.114	0.254	0.443	0.637	0.791	0.892
135.	0.032	0.095	0.224	0.408	0.604	0.767	0.878
145.	0.005	0.018	0.061	0.158	0.321	0.518	0.700
155.	0.000	0.000	0.001	0.003	0.014	0.048	0.138
165.	0.000	0.000	0.002	0.006	0.024	0.074	0.178
175.	0.001	0.003	0.012	0.041	0.113	0.243	0.418
185.	0.002	0.009	0.032	0.074	0.213	0.384	0.573
195.	0.005	0.020	0.070	0.197	0.415	0.664	0.872
AVE =	0.010	0.030	0.377	0.162	0.283	0.428	0.574
	14.	16.	18.	20.	22.	24.	
105.	0.537	0.737	0.880	0.956	0.987	0.997	
115.	0.889	0.947	0.976	0.990	0.996	0.998	
125.	0.948	0.977	0.996	0.996	0.998	0.999	
135.	0.941	0.973	0.988	0.995	0.998	0.999	
145.	0.835	0.917	0.962	0.983	0.993	0.997	
155.	0.308	0.539	0.756	0.900	0.967	0.991	
165.	0.336	0.528	0.698	0.821	0.906	0.955	
175.	0.600	0.754	0.864	0.931	0.968	0.996	
185.	0.756	0.885	0.957	0.987	0.997	0.999	
195.	0.950	0.986	0.997	0.999	1.000	1.000	
AVE =	0.710	0.824	0.906	0.956	0.981	0.992	

TABLE IX
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$
 $P_F = 10^{-5}$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.007	0.024	0.068	0.161
115.	0.004	0.012	0.037	0.092	0.187	0.318	0.464
125.	0.013	0.039	0.095	0.192	0.323	0.478	0.609
135.	0.010	0.032	0.082	0.172	0.298	0.444	0.585
145.	0.002	0.006	0.020	0.055	0.126	0.238	0.378
155.	0.000	0.000	0.001	0.003	0.009	0.030	0.087
165.	0.001	0.002	0.008	0.025	0.067	0.147	0.266
175.	0.004	0.013	0.040	0.098	0.196	0.328	0.475
185.	0.011	0.032	0.082	0.172	0.299	0.446	0.589
195.	0.015	0.044	0.109	0.222	0.380	0.557	0.718
AVE =	0.006	0.018	0.048	0.104	0.191	0.305	0.433
	14.	16.	18.	20.	22.	24.	
105.	0.310	0.495	0.674	0.813	0.904	0.954	
115.	0.604	0.721	0.812	0.878	0.925	0.956	
125.	0.725	0.813	0.876	0.919	0.948	0.967	
135.	0.706	0.799	0.867	0.913	0.944	0.964	
145.	0.524	0.656	0.764	0.845	0.904	0.944	
155.	0.290	0.369	0.561	0.732	0.854	0.927	
165.	0.409	0.553	0.680	0.780	0.853	0.904	
175.	0.613	0.728	0.815	0.878	0.920	0.949	
185.	0.713	0.812	0.885	0.935	0.966	0.983	
195.	0.840	0.917	0.961	0.982	0.992	0.997	
AVE =	0.564	0.687	0.790	0.868	0.921	0.955	

TABLE IX (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$
 $P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.003	0.009	0.030	0.085	0.194
115.	0.005	0.016	0.047	0.113	0.220	0.359	0.507
125.	0.017	0.049	0.116	0.225	0.365	0.513	0.646
135.	0.014	0.041	0.101	0.203	0.339	0.487	0.624
145.	0.002	0.008	0.026	0.069	0.152	0.275	0.421
155.	0.000	0.000	0.001	0.003	0.012	0.039	0.109
165.	0.001	0.003	0.010	0.032	0.083	0.175	0.305
175.	0.005	0.017	0.051	0.119	0.230	0.370	0.517
185.	0.014	0.041	0.101	0.204	0.340	0.489	0.628
195.	0.019	0.056	0.133	0.261	0.429	0.607	0.759
AVE =	0.008	0.023	0.059	0.124	0.220	0.340	0.471
	14.	16.	18.	20.	22.	24.	
105.	0.359	0.549	0.720	0.845	0.922	0.964	
115.	0.642	0.752	0.835	0.894	0.936	0.963	
125.	0.754	0.835	0.891	0.930	0.955	0.971	
135.	0.737	0.822	0.883	0.924	0.951	0.969	
145.	0.566	0.692	0.791	0.865	0.918	0.953	
155.	0.239	0.422	0.614	0.773	0.880	0.942	
165.	0.452	0.594	0.713	0.805	0.871	0.916	
175.	0.651	0.758	0.837	0.893	0.931	0.955	
185.	0.746	0.837	0.902	0.946	0.973	0.987	
195.	0.867	0.933	0.969	0.986	0.994	0.998	
AVE =	0.601	0.719	0.816	0.886	0.933	0.962	

TABLE IX (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$T_1 = 1/4010$

$T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.004	0.017	0.059	0.166	0.356
115.	0.009	0.032	0.094	0.219	0.400	0.596	0.761
125.	0.033	0.098	0.226	0.408	0.603	0.766	0.876
135.	0.027	0.082	0.158	0.373	0.570	0.741	0.860
145.	0.004	0.015	0.051	0.138	0.289	0.482	0.670
155.	0.000	0.000	0.001	0.006	0.022	0.077	0.209
165.	0.001	0.005	0.020	0.064	0.165	0.328	0.524
175.	0.010	0.034	0.101	0.231	0.415	0.609	0.771
185.	0.027	0.083	0.199	0.374	0.571	0.742	0.863
195.	0.038	0.110	0.253	0.459	0.675	0.843	0.939
AVE =	0.015	0.046	0.115	0.229	0.377	0.535	0.683
	14.	16.	18.	20.	22.	24.	
105.	0.591	0.794	0.918	0.974	0.993	0.998	
115.	0.873	0.939	0.972	0.989	0.996	0.999	
125.	0.940	0.973	0.988	0.995	0.998	0.999	
135.	0.931	0.969	0.986	0.994	0.998	0.999	
145.	0.814	0.905	0.956	0.981	0.993	0.998	
155.	0.426	0.665	0.847	0.945	0.984	0.996	
165.	0.704	0.837	0.918	0.962	0.983	0.993	
175.	0.879	0.942	0.973	0.988	0.995	0.998	
185.	0.935	0.973	0.990	0.997	0.999	1.000	
195.	0.981	0.995	0.999	1.000	1.000	1.000	
AVE =	0.807	0.899	0.955	0.983	0.994	0.998	

TABLE IX (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$
 $P_F = 10^{-5}$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.021	0.071	0.191	0.394
115.	0.011	0.038	0.110	0.247	0.435	0.630	0.786
125.	0.040	0.114	0.254	0.443	0.637	0.791	0.892
135.	0.032	0.096	0.224	0.408	0.604	0.767	0.878
145.	0.005	0.018	0.061	0.158	0.321	0.518	0.700
155.	0.000	0.001	0.002	0.007	0.027	0.091	0.239
165.	0.002	0.006	0.024	0.076	0.188	0.361	0.559
175.	0.012	0.041	0.118	0.259	0.450	0.643	0.795
185.	0.032	0.097	0.225	0.408	0.605	0.789	0.880
195.	0.045	0.128	0.284	0.498	0.710	0.866	0.950
AVE =	0.018	0.054	0.131	0.253	0.405	0.563	0.707
	14.	16.	18.	20.	22.	24.	
105.	0.631	0.822	0.933	0.980	0.995	0.999	
115.	0.889	0.947	0.977	0.991	0.996	0.999	
125.	0.948	0.977	0.990	0.996	0.998	0.999	
135.	0.941	0.973	0.988	0.995	0.998	0.999	
145.	0.835	0.918	0.963	0.985	0.994	0.998	
155.	0.467	0.703	0.871	0.956	0.988	0.997	
165.	0.733	0.856	0.929	0.968	0.986	0.994	
175.	0.894	0.950	0.978	0.990	0.996	0.998	
185.	0.945	0.977	0.992	0.998	0.999	1.000	
195.	0.985	0.996	0.999	1.000	1.000	1.000	
AVE =	0.827	0.912	0.962	0.986	0.995	0.998	

TABLE X

DETECTION PROBABILITY FOR COHERENT MTI MODEBeam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$ $P_F = 10^{-5}$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.008	0.025	0.074	0.181
115.	0.004	0.013	0.041	0.103	0.213	0.381	0.564
125.	0.014	0.042	0.107	0.223	0.388	0.571	0.733
135.	0.011	0.035	0.092	0.199	0.356	0.539	0.707
145.	0.002	0.007	0.022	0.061	0.144	0.280	0.456
155.	0.000	0.000	0.001	0.003	0.010	0.033	0.095
165.	0.001	0.002	0.008	0.027	0.074	0.168	0.315
175.	0.004	0.015	0.044	0.110	0.228	0.394	0.577
185.	0.011	0.035	0.092	0.199	0.357	0.540	0.710
195.	0.016	0.048	0.122	0.257	0.448	0.657	0.827
AVE =	0.006	0.020	0.053	0.119	0.225	0.364	0.517
	14.	16.	18.	20.	22.	24.	
105.	0.358	0.579	0.778	0.907	0.969	0.992	
115.	0.728	0.849	0.924	0.965	0.985	0.995	
125.	0.652	0.925	0.965	0.984	0.993	0.997	
135.	0.834	0.915	0.960	0.982	0.992	0.997	
145.	0.636	0.784	0.886	0.946	0.977	0.991	
155.	0.225	0.426	0.652	0.833	0.937	0.981	
165.	0.495	0.670	0.809	0.900	0.952	0.978	
175.	0.738	0.855	0.927	0.966	0.985	0.993	
185.	0.839	0.922	0.967	0.988	0.996	0.999	
195.	0.930	0.977	0.994	0.999	1.000	1.000	
AVE =	0.664	0.790	0.886	0.947	0.979	0.992	

TABLE X (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODEBeam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$ $P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
15.	0.000	0.001	0.003	0.010	0.033	0.094	0.219
15.	0.005	0.017	0.052	0.127	0.257	0.431	0.615
18.	0.018	0.054	0.131	0.263	0.439	0.621	0.773
13.	0.015	0.045	0.114	0.236	0.406	0.590	0.750
145.	0.002	0.008	0.028	0.077	0.174	0.325	0.508
155.	0.000	0.000	0.001	0.004	0.013	0.042	0.120
165.	0.001	0.003	0.011	0.035	0.093	0.202	0.363
175.	0.006	0.019	0.055	0.135	0.269	0.445	0.627
185.	0.015	0.045	0.114	0.237	0.407	0.592	0.753
195.	0.021	0.061	0.150	0.303	0.506	0.711	0.864
AVE =	0.008	0.025	0.066	0.143	0.260	0.405	0.559
	14.	16.	18.	20.	22.	24.	
105.	0.415	0.639	0.823	0.931	0.979	0.994	
115.	0.769	0.876	0.939	0.973	0.989	0.996	
125.	0.876	0.940	0.972	0.988	0.995	0.998	
135.	0.863	0.932	0.968	0.986	0.994	0.997	
145.	0.684	0.819	0.908	0.957	0.982	0.994	
155.	0.271	0.487	0.709	0.871	0.955	0.987	
165.	0.347	0.716	0.841	0.919	0.962	0.983	
175.	0.178	0.881	0.942	0.973	0.988	0.995	
185.	0.868	0.938	0.975	0.991	0.997	0.999	
195.	0.949	0.984	0.996	0.999	1.000	1.000	
AVE =	0.702	0.821	0.907	0.959	0.984	0.994	

TABLE X (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODEBeam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$ $P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.018	0.064	0.181	0.397
115.	0.009	0.034	0.103	0.245	0.460	0.688	0.859
125.	0.035	0.107	0.253	0.469	0.696	0.864	0.952
135.	0.028	0.089	0.221	0.427	0.658	0.840	0.941
145.	0.004	0.016	0.055	0.151	0.327	0.557	0.768
155.	0.000	0.000	0.002	0.006	0.024	0.082	0.228
165.	0.001	0.005	0.021	0.069	0.182	0.373	0.605
175.	0.010	0.037	0.110	0.259	0.477	0.703	0.868
185.	0.029	0.089	0.221	0.428	0.659	0.841	0.943
195.	0.040	0.120	0.283	0.522	0.763	0.919	0.982
AVE =	0.016	0.050	0.127	0.260	0.431	0.605	0.754
	14.	16.	18.	20.	22.	24.	
105.	0.664	0.873	0.969	0.995	1.000	1.000	
115.	0.950	0.986	0.997	0.999	1.000	1.000	
125.	0.986	0.997	0.999	1.000	1.000	1.000	
135.	0.983	0.996	0.999	1.000	1.000	1.000	
145.	0.905	0.969	0.992	0.998	1.000	1.000	
155.	0.474	0.742	0.917	0.984	0.998	1.000	
165.	0.804	0.924	0.976	0.994	0.999	1.000	
175.	0.954	0.987	0.997	0.999	1.000	1.000	
185.	0.984	0.996	0.999	1.000	1.000	1.000	
195.	0.997	1.000	1.000	1.000	1.000	1.000	
AVE =	0.870	0.947	0.985	0.997	1.000	1.000	

TABLE X (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODEBeam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.002	0.006	0.022	0.076	0.209	0.441
115.	0.011	0.041	0.120	0.277	0.500	0.724	0.881
125.	0.043	0.125	0.285	0.510	0.732	0.886	0.961
135.	0.034	0.105	0.250	0.468	0.696	0.864	0.953
145.	0.005	0.019	0.065	0.175	0.364	0.597	0.799
155.	0.000	0.001	0.002	0.007	0.029	0.098	0.262
165.	0.002	0.007	0.026	0.082	0.208	0.412	0.645
175.	0.012	0.044	0.129	0.292	0.518	0.738	0.889
185.	0.034	0.105	0.251	0.468	0.697	0.866	0.954
195.	0.048	0.140	0.319	0.566	0.798	0.936	0.987
AVE =	0.019	0.059	0.145	0.287	0.462	0.633	0.777
	14.	16.	18.	20.	22.	24.	
105.	0.708	0.898	0.977	0.997	1.000	1.000	
115.	0.960	0.989	0.997	1.000	1.000	1.000	
125.	0.989	0.998	0.999	1.000	1.000	1.000	
135.	0.987	0.997	0.999	1.000	1.000	1.000	
145.	0.922	0.976	0.994	0.999	1.000	1.000	
155.	0.521	0.781	0.936	0.988	0.999	1.000	
165.	0.832	0.938	0.982	0.995	0.999	1.000	
175.	0.963	0.990	0.998	1.000	1.000	1.000	
185.	0.988	0.997	1.000	1.000	1.000	1.000	
195.	0.998	1.000	1.000	1.000	1.000	1.000	
AVE =	0.887	0.956	0.988	0.998	1.000	1.000	

TABLE XI

DETECTION PROBABILITY FOR COHERENT MTI MODE

Scan Numbers A, B, C, D, E, F, G and H

$$T_1 = 1/4010 \quad T_2 = 1/2643$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.008	0.026	0.076	0.186
115.	0.004	0.014	0.041	0.106	0.226	0.401	0.602
125.	0.014	0.043	0.110	0.232	0.409	0.609	0.783
135.	0.012	0.036	0.094	0.206	0.374	0.574	0.756
145.	0.002	0.007	0.022	0.062	0.148	0.293	0.484
155.	0.000	0.000	0.001	0.003	0.010	0.034	0.097
165.	0.001	0.003	0.009	0.028	0.076	0.174	0.330
175.	0.004	0.015	0.045	0.113	0.237	0.415	0.616
185.	0.012	0.036	0.094	0.206	0.375	0.576	0.759
195.	0.016	0.049	0.125	0.266	0.471	0.694	0.867
AVE =	0.007	0.020	0.054	0.123	0.235	0.385	0.548
	14.	16.	18.	20.	22.	24.	
105.	0.372	0.607	0.815	0.938	0.985	0.997	
115.	0.778	0.897	0.960	0.987	0.997	0.999	
125.	0.900	0.961	0.987	0.996	0.999	1.000	
135.	0.884	0.953	0.984	0.995	0.999	1.000	
145.	0.680	0.835	0.930	0.975	0.993	0.998	
155.	0.231	0.442	0.682	0.868	0.962	0.992	
165.	0.526	0.717	0.859	0.941	0.979	0.994	
175.	0.788	0.903	0.962	0.988	0.996	0.999	
185.	0.888	0.958	0.987	0.997	0.999	1.000	
195.	0.958	0.991	0.998	1.000	1.000	1.000	
AVE =	0.701	0.826	0.917	0.969	0.991	0.99X	

TABLE XI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.003	0.010	0.033	0.096	0.226
115.	0.005	0.018	0.053	0.131	0.258	0.456	0.656
125.	0.018	0.055	0.135	0.274	0.464	0.663	0.823
135.	0.015	0.046	0.117	0.245	0.428	0.629	0.799
145.	0.002	0.009	0.028	0.078	0.180	0.341	0.540
155.	0.000	0.000	0.001	0.004	0.013	0.043	0.122
165.	0.001	0.003	0.011	0.036	0.095	0.209	0.381
175.	0.006	0.019	0.057	0.139	0.280	0.470	0.669
185.	0.015	0.046	0.117	0.246	0.429	0.631	0.802
195.	0.021	0.062	0.154	0.314	0.532	0.750	0.901
AVE =	0.002	0.026	0.067	0.148	0.272	0.429	0.592
	14.	16.	18.	20.	22.	24.	
105.	0.432	0.670	0.859	0.958	0.991	0.999	
115.	0.819	0.921	0.971	0.991	0.998	1.000	
125.	0.923	0.971	0.991	0.997	0.999	1.000	
135.	0.909	0.966	0.989	0.997	0.999	1.000	
145.	0.730	0.869	0.947	0.983	0.995	0.999	
155.	0.278	0.506	0.742	0.904	0.975	0.995	
165.	0.583	0.764	0.889	0.956	0.985	0.996	
175.	0.828	0.925	0.972	0.991	0.998	0.999	
185.	0.914	0.970	0.992	0.998	1.000	1.000	
195.	0.972	0.994	0.999	1.000	1.000	1.000	
AVE =	0.739	0.856	0.935	0.977	0.994	0.999	

TABLE XI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/4010 \quad T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.018	0.065	0.184	0.407
115.	0.009	0.034	0.104	0.251	0.476	0.718	0.892
125.	0.036	0.108	0.259	0.486	0.727	0.896	0.973
135.	0.029	0.091	0.225	0.442	0.687	0.874	0.964
145.	0.004	0.016	0.056	0.154	0.336	0.579	0.802
155.	0.000	0.001	0.002	0.006	0.024	0.083	0.232
165.	0.001	0.006	0.021	0.070	0.186	0.385	0.631
175.	0.010	0.037	0.112	0.265	0.494	0.734	0.900
185.	0.029	0.091	0.226	0.442	0.688	0.875	0.965
195.	0.041	0.122	0.290	0.540	0.792	0.944	0.992
AVE =	0.016	0.051	0.130	0.268	0.447	0.627	0.776
	14.	16.	18.	20.	22.	24.	
105.	0.687	0.899	0.983	0.999	1.000	1.000	
115.	0.971	0.994	0.999	1.000	1.000	1.000	
125.	0.995	0.999	1.000	1.000	1.000	1.000	
135.	0.993	0.999	1.000	1.000	1.000	1.000	
145.	0.934	0.985	0.998	1.000	1.000	1.000	
155.	0.486	0.765	0.940	0.992	0.999	1.000	
165.	0.838	0.950	0.989	0.998	1.000	1.000	
175.	0.974	0.995	0.999	1.000	1.000	1.000	
185.	0.994	0.999	1.000	1.000	1.000	1.000	
195.	0.999	1.000	1.000	1.000	1.000	1.000	
AVE =	0.887	0.959	0.991	0.999	1.000	1.000	

TABLE XI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$$\bar{T}_1 = 1/4010 \quad \bar{T}_2 = 1/2645$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.002	0.006	0.023	0.077	0.213	0.452
115.	0.011	0.041	0.122	0.284	0.519	0.756	0.913
125.	0.043	0.127	0.292	0.529	0.764	0.917	0.979
135.	0.035	0.106	0.256	0.484	0.726	0.897	0.973
145.	0.005	0.020	0.066	0.178	0.375	0.622	0.833
155.	0.000	0.001	0.002	0.008	0.029	0.099	0.266
165.	0.002	0.007	0.026	0.083	0.213	0.425	0.673
175.	0.013	0.045	0.131	0.299	0.537	0.771	0.920
185.	0.035	0.107	0.257	0.485	0.727	0.898	0.974
195.	0.049	0.142	0.327	0.586	0.828	0.958	0.995
AVE =	0.019	0.068	0.148	0.296	0.480	0.656	0.798
	14.	16.	18.	20.	22.	24.	
105.	0.731	0.922	0.989	0.999	1.000	1.000	
115.	0.378	0.996	0.999	1.000	1.000	1.000	
125.	0.996	0.999	1.000	1.000	1.000	1.000	
135.	0.995	0.999	1.000	1.000	1.000	1.000	
145.	0.949	0.989	0.998	1.000	1.000	1.000	
155.	0.534	0.805	0.956	0.995	1.000	1.000	
165.	0.866	0.962	0.992	0.999	1.000	1.000	
175.	0.980	0.997	1.000	1.000	1.000	1.000	
185.	0.995	0.999	1.000	1.000	1.000	1.000	
195.	1.000	1.000	1.000	1.000	1.000	1.000	
AVE =	0.982	0.967	0.993	0.999	1.000	1.000	

TABLE XII
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$$T_1 = 1/3268$$

$$T_2 = 1/4350$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE I

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.004	0.013	0.037	0.090	0.180
115.	0.000	0.000	0.001	0.003	0.011	0.033	0.081
125.	0.000	0.000	0.000	0.001	0.004	0.014	0.043
135.	0.001	0.003	0.009	0.028	0.074	0.159	0.282
145.	0.006	0.019	0.053	0.122	0.232	0.371	0.517
155.	0.013	0.039	0.096	0.194	0.326	0.473	0.611
165.	0.012	0.036	0.089	0.183	0.312	0.459	0.599
175.	0.004	0.013	0.039	0.097	0.194	0.327	0.473
185.	0.000	0.001	0.004	0.015	0.043	0.104	0.206
195.	0.000	0.000	0.000	0.001	0.002	0.006	0.021
AVE =	0.004	0.011	0.030	0.066	0.124	0.203	0.301
	14.	16.	18.	20.	22.	24.	
105.	0.302	0.441	0.577	0.696	0.789	0.859	
115.	0.166	0.285	0.423	0.561	0.685	0.786	
125.	0.115	0.247	0.429	0.620	0.777	0.883	
135.	0.428	0.573	0.702	0.805	0.881	0.933	
145.	0.649	0.756	0.836	0.892	0.930	0.955	
155.	0.726	0.814	0.877	0.920	0.948	0.967	
165.	0.717	0.807	0.872	0.917	0.946	0.966	
175.	0.611	0.727	0.815	0.877	0.920	0.949	
185.	0.342	0.491	0.632	0.752	0.845	0.911	
195.	0.064	0.157	0.310	0.501	0.684	0.823	
AVE =	0.412	0.530	0.647	0.754	0.841	0.903	

TABLE XII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.017	0.047	0.110	0.211
115.	0.000	0.000	0.001	0.004	0.014	0.042	0.100
125.	0.000	0.000	0.000	0.001	0.005	0.018	0.056
135.	0.001	0.003	0.012	0.036	0.092	0.189	0.322
145.	0.007	0.024	0.066	0.147	0.268	0.413	0.559
155.	0.017	0.050	0.118	0.227	0.368	0.515	0.649
165.	0.015	0.045	0.109	0.215	0.353	0.501	0.637
175.	0.005	0.017	0.050	0.118	0.228	0.368	0.516
185.	0.000	0.002	0.006	0.019	0.055	0.127	0.241
195.	0.000	0.000	0.000	0.001	0.002	0.008	0.028
AVE =	0.005	0.014	0.037	0.079	0.143	0.229	0.332
	14.	16.	18.	20.	22.	24.	
105.	0.341	0.482	0.615	0.727	0.813	0.876	
115.	0.195	0.323	0.464	0.600	0.717	0.811	
125.	0.143	0.293	0.484	0.671	0.814	0.905	
135.	0.471	0.614	0.735	0.830	0.899	0.945	
145.	0.685	0.784	0.856	0.906	0.939	0.961	
155.	0.756	0.836	0.892	0.930	0.955	0.971	
165.	0.747	0.830	0.888	0.927	0.953	0.970	
175.	0.649	0.757	0.836	0.892	0.930	0.955	
185.	0.384	0.534	0.670	0.783	0.868	0.926	
195.	0.081	0.191	0.360	0.556	0.730	0.854	
AVE =	0.445	0.564	0.680	0.782	0.862	0.917	

TABLE XII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/3268$

$T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.003	0.011	0.039	0.110	0.238	0.411
115.	0.000	0.001	0.002	0.009	0.034	0.097	0.217
125.	0.000	0.000	0.001	0.003	0.011	0.041	0.130
135.	0.002	0.007	0.028	0.086	0.206	0.385	0.583
145.	0.017	0.058	0.152	0.312	0.508	0.693	0.830
155.	0.041	0.116	0.256	0.447	0.640	0.793	0.893
165.	0.036	0.106	0.240	0.428	0.623	0.781	0.886
175.	0.011	0.041	0.116	0.257	0.448	0.640	0.794
185.	0.001	0.003	0.013	0.046	0.127	0.274	0.468
195.	0.000	0.000	0.000	0.001	0.005	0.018	0.065
AVE =	0.011	0.034	0.082	0.163	0.271	0.396	0.528
	14.	16.	18.	20.	22.	24.	
105.	0.594	0.750	0.861	0.929	0.967	0.985	
115.	0.387	0.571	0.732	0.850	0.926	0.968	
125.	0.311	0.558	0.781	0.916	0.975	0.994	
135.	0.753	0.871	0.941	0.977	0.992	0.998	
145.	0.914	0.960	0.982	0.992	0.997	0.999	
155.	0.949	0.977	0.990	0.996	0.998	0.999	
165.	0.945	0.975	0.989	0.996	0.998	0.999	
175.	0.893	0.949	0.977	0.990	0.996	0.998	
185.	0.660	0.810	0.908	0.961	0.986	0.996	
195.	0.185	0.397	0.647	0.842	0.945	0.985	
AVE =	0.659	0.782	0.881	0.945	0.978	0.992	

TABLE XII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.002	0.009	0.033	0.095	0.212	0.379
115.	0.000	0.001	0.002	0.008	0.028	0.083	0.193
125.	0.000	0.000	0.001	0.002	0.009	0.034	0.110
135.	0.001	0.006	0.023	0.073	0.181	0.351	0.548
145.	0.014	0.048	0.132	0.281	0.473	0.661	0.808
155.	0.034	0.100	0.228	0.411	0.606	0.768	0.878
165.	0.030	0.091	0.213	0.393	0.589	0.755	0.870
175.	0.009	0.034	0.100	0.229	0.412	0.607	0.769
185.	0.001	0.003	0.011	0.038	0.110	0.245	0.432
195.	0.000	0.000	0.000	0.001	0.004	0.015	0.054
AVE =	0.009	0.028	0.072	0.147	0.251	0.373	0.504
	14.	16.	18.	20.	22.	24.	
105.	0.562	0.724	0.843	0.919	0.961	0.982	
115.	0.355	0.538	0.705	0.832	0.914	0.961	
125.	0.274	0.514	0.746	0.898	0.968	0.992	
135.	0.725	0.853	0.931	0.972	0.990	0.997	
145.	0.901	0.953	0.979	0.991	0.996	0.998	
155.	0.941	0.973	0.988	0.995	0.998	0.999	
165.	0.936	0.971	0.987	0.995	0.998	0.999	
175.	0.878	0.941	0.973	0.988	0.995	0.998	
185.	0.627	0.786	0.893	0.954	0.983	0.995	
195.	0.159	0.356	0.605	0.813	0.932	0.960	
AVE =	0.636	0.761	0.865	0.936	0.974	0.990	

TABLE XIII
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$$T_1 = 1/4950 \quad T_2 = 1/3268$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.013	0.039	0.095	0.192	0.323	0.470
115.	0.001	0.003	0.011	0.034	0.085	0.177	0.305
125.	0.000	0.000	0.001	0.005	0.016	0.046	0.111
135.	0.000	0.000	0.001	0.003	0.010	0.030	0.079
145.	0.000	0.002	0.006	0.019	0.051	0.115	0.217
155.	0.001	0.004	0.013	0.038	0.092	0.182	0.304
165.	0.001	0.003	0.012	0.035	0.085	0.172	0.292
175.	0.000	0.001	0.004	0.013	0.038	0.092	0.182
185.	0.000	0.000	0.000	0.001	0.005	0.016	0.048
195.	0.000	0.000	0.001	0.004	0.014	0.040	0.098
AVE =	0.001	0.003	0.009	0.025	0.059	0.119	0.211
	14.	16.	18.	20.	22.	24.	
105.	0.609	0.725	0.813	0.876	0.919	0.948	
115.	0.451	0.591	0.711	0.803	0.869	0.915	
125.	0.219	0.367	0.533	0.689	0.814	0.899	
135.	0.173	0.318	0.496	0.672	0.811	0.902	
145.	0.347	0.487	0.619	0.731	0.820	0.886	
155.	0.444	0.580	0.698	0.791	0.860	0.908	
165.	0.430	0.567	0.687	0.783	0.854	0.904	
175.	0.305	0.444	0.581	0.700	0.795	0.867	
185.	0.118	0.242	0.413	0.598	0.758	0.870	
195.	0.198	0.335	0.490	0.641	0.769	0.865	
AVE =	0.329	0.465	0.604	0.728	0.827	0.896	

TABLE XIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4950$

$T_2 = 1/3268$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.017	0.049	0.116	0.225	0.365	0.513
115.	0.001	0.004	0.014	0.043	0.105	0.209	0.345
125.	0.000	0.000	0.002	0.006	0.021	0.058	0.135
135.	0.000	0.000	0.001	0.004	0.013	0.038	0.098
145.	0.001	0.002	0.007	0.024	0.064	0.139	0.251
155.	0.001	0.005	0.017	0.048	0.112	0.213	0.343
165.	0.001	0.004	0.015	0.044	0.104	0.202	0.330
175.	0.000	0.001	0.005	0.017	0.048	0.112	0.213
185.	0.000	0.000	0.001	0.002	0.006	0.021	0.061
195.	0.000	0.000	0.001	0.005	0.018	0.051	0.120
AVE =	0.001	0.004	0.011	0.031	0.071	0.141	0.241
	14.	16.	18.	20.	22.	24.	
105.	0.646	0.754	0.835	0.891	0.930	0.955	
115.	0.493	0.630	0.742	0.826	0.885	0.926	
125.	0.257	0.413	0.580	0.730	0.843	0.917	
135.	0.206	0.365	0.548	0.717	0.843	0.921	
145.	0.387	0.527	0.655	0.761	0.842	0.901	
155.	0.485	0.617	0.729	0.814	0.876	0.919	
165.	0.471	0.605	0.719	0.807	0.871	0.916	
175.	0.344	0.485	0.613	0.731	0.819	0.885	
185.	0.145	0.284	0.465	0.649	0.797	0.894	
195.	0.232	0.378	0.535	0.681	0.801	0.887	
AVE =	0.367	0.506	0.643	0.761	0.851	0.912	

TABLE XIII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$$T_1 = 1/4950 \quad T_2 = 1/3268$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.009	0.033	0.098	0.225	0.408	0.603	0.766
115.	0.002	0.008	0.028	0.086	0.205	0.382	0.578
125.	0.000	0.001	0.003	0.012	0.041	0.116	0.258
135.	0.000	0.000	0.002	0.007	0.024	0.075	0.190
145.	0.001	0.004	0.014	0.048	0.126	0.262	0.439
155.	0.002	0.009	0.034	0.096	0.215	0.382	0.565
165.	0.002	0.008	0.030	0.088	0.201	0.365	0.548
175.	0.001	0.002	0.010	0.034	0.096	0.215	0.383
185.	0.000	0.000	0.001	0.003	0.012	0.042	0.120
195.	0.200	0.001	0.002	0.010	0.035	0.102	0.233
AVE =	0.002	0.007	0.022	0.061	0.136	0.255	0.408
	14.	16.	18.	20.	22.	24.	
105.	0.876	0.940	0.973	0.988	0.995	0.998	
115.	0.747	0.865	0.934	0.970	0.987	0.994	
125.	0.456	0.663	0.829	0.930	0.977	0.994	
135.	0.376	0.604	0.803	0.924	0.977	0.994	
145.	0.619	0.768	0.873	0.938	0.973	0.989	
155.	0.726	0.845	0.920	0.962	0.983	0.993	
165.	0.713	0.836	0.914	0.959	0.981	0.992	
175.	0.566	0.727	0.846	0.922	0.964	0.986	
185.	0.275	0.497	0.723	0.882	0.961	0.989	
195.	0.419	0.619	0.788	0.901	0.962	0.988	
AVE =	0.577	0.736	0.860	0.937	0.976	0.992	

TABLE XIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$$T_1 = 1/4950 \quad T_2 = 1/3268$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.011	0.040	0.114	0.253	0.443	0.636	0.791
115.	0.002	0.009	0.034	0.101	0.231	0.417	0.613
125.	0.000	0.001	0.004	0.014	0.049	0.135	0.289
135.	0.000	0.001	0.002	0.008	0.029	0.089	0.216
145.	0.001	0.005	0.017	0.057	0.145	0.291	0.472
155.	0.003	0.012	0.040	0.111	0.240	0.415	0.597
165.	0.003	0.010	0.036	0.102	0.226	0.397	0.580
175.	0.001	0.003	0.012	0.040	0.112	0.241	0.415
185.	0.000	0.000	0.001	0.004	0.014	0.050	0.140
195.	0.000	0.001	0.003	0.012	0.042	0.119	0.261
AVE =	0.002	0.008	0.026	0.070	0.153	0.279	0.437
	14.	16.	18.	20.	22.	24.	
105.	0.892	0.948	0.977	0.990	0.996	0.998	
115.	0.774	0.881	0.943	0.974	0.989	0.995	
125.	0.493	0.697	0.853	0.942	0.982	0.995	
135.	0.414	0.643	0.831	0.938	0.982	0.996	
145.	0.649	0.791	0.888	0.946	0.977	0.991	
155.	0.752	0.862	0.930	0.967	0.985	0.994	
165.	0.739	0.854	0.925	0.965	0.984	0.993	
175.	0.598	0.753	0.864	0.932	0.970	0.988	
185.	0.308	0.538	0.758	0.902	0.969	0.992	
195.	0.455	0.653	0.813	0.916	0.969	0.991	
AVE =	0.607	0.762	0.878	0.947	0.980	0.993	

TABLE XIV
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$$T_1 = 1/3268 \quad T_2 = 1/4950 \\ P_F = 10^{-5}$$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.013	0.039	0.095	0.192	0.323	0.470
115.	0.001	0.003	0.011	0.034	0.085	0.177	0.305
125.	0.000	0.000	0.002	0.005	0.018	0.054	0.133
135.	0.001	0.003	0.009	0.029	0.075	0.161	0.287
145.	0.006	0.019	0.053	0.122	0.232	0.371	0.517
155.	0.013	0.039	0.096	0.194	0.326	0.473	0.611
165.	0.012	0.036	0.089	0.183	0.312	0.459	0.599
175.	0.004	0.013	0.039	0.097	0.194	0.327	0.473
185.	0.000	0.001	0.004	0.015	0.044	0.106	0.211
195.	0.000	0.000	0.001	0.004	0.014	0.042	0.105
AVE =	0.004	0.013	0.034	0.078	0.149	0.249	0.371
	14.	16.	18.	20.	22.	24.	
105.	0.609	0.725	0.813	0.876	0.919	0.948	
115.	0.451	0.591	0.711	0.803	0.870	0.916	
125.	0.267	0.444	0.627	0.779	0.882	0.942	
135.	0.440	0.596	0.734	0.841	0.914	0.957	
145.	0.649	0.757	0.836	0.893	0.931	0.957	
155.	0.726	0.814	0.877	0.920	0.948	0.967	
165.	0.717	0.807	0.872	0.917	0.946	0.966	
175.	0.612	0.727	0.815	0.878	0.921	0.950	
185.	0.353	0.514	0.668	0.795	0.885	0.941	
195.	0.216	0.371	0.547	0.710	0.833	0.913	
AVE =	0.504	0.635	0.750	0.841	0.905	0.946	

TABLE XIV (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.017	0.049	0.116	0.225	0.365	0.513
115.	0.001	0.004	0.014	0.043	0.105	0.209	0.345
125.	0.000	0.001	0.002	0.007	0.024	0.068	0.162
135.	0.001	0.003	0.012	0.037	0.093	0.191	0.328
145.	0.007	0.024	0.066	0.147	0.268	0.413	0.559
155.	0.017	0.050	0.118	0.227	0.368	0.515	0.649
165.	0.015	0.045	0.109	0.215	0.353	0.501	0.637
175.	0.005	0.017	0.050	0.118	0.228	0.368	0.516
185.	0.000	0.002	0.006	0.019	0.035	0.129	0.246
195.	0.000	0.000	0.001	0.005	0.018	0.053	0.128
AVE =	0.005	0.016	0.043	0.094	0.174	0.281	0.408
	14.	16.	18.	20.	22.	24.	
105.	0.646	0.754	0.835	0.891	0.930	0.955	
115.	0.493	0.630	0.742	0.826	0.886	0.927	
125.	0.312	0.497	0.676	0.814	0.904	0.954	
135.	0.485	0.639	0.770	0.866	0.929	0.966	
145.	0.685	0.784	0.856	0.906	0.940	0.963	
155.	0.756	0.836	0.892	0.930	0.955	0.971	
165.	0.747	0.830	0.888	0.927	0.953	0.970	
175.	0.649	0.757	0.837	0.893	0.931	0.957	
185.	0.398	0.560	0.708	0.826	0.905	0.953	
195.	0.254	0.420	0.597	0.750	0.862	0.930	
AVE =	0.540	0.671	0.780	0.863	0.920	0.955	

TABLE XIV (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$$T_1 = 1/3268$$

$$T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.009	0.033	0.098	0.225	0.408	0.683	0.766
115.	0.002	0.006	0.026	0.086	0.205	0.382	0.578
125.	0.000	0.001	0.003	0.013	0.046	0.134	0.303
135.	0.002	0.006	0.023	0.073	0.182	0.353	0.555
145.	0.014	0.048	0.132	0.281	0.473	0.661	0.808
155.	0.034	0.100	0.288	0.411	0.606	0.768	0.878
165.	0.038	0.091	0.213	0.393	0.589	0.755	0.870
175.	0.009	0.034	0.100	0.229	0.412	0.607	0.769
185.	0.001	0.003	0.011	0.038	0.111	0.248	0.439
195.	0.000	0.001	0.002	0.010	0.036	0.106	0.246
AVE =	0.010	0.032	0.084	0.176	0.367	0.462	0.621
	14.	16.	18.	20.	22.	24.	
105.	0.876	0.940	0.973	0.986	0.995	0.998	
115.	0.747	0.865	0.934	0.970	0.987	0.995	
125.	0.530	0.746	0.891	0.963	0.990	0.998	
135.	0.737	0.869	0.945	0.981	0.994	0.999	
145.	0.901	0.953	0.979	0.991	0.996	0.999	
155.	0.941	0.973	0.988	0.995	0.998	0.999	
165.	0.936	0.971	0.987	0.995	0.998	0.999	
175.	0.878	0.941	0.973	0.988	0.995	0.998	
185.	0.641	0.806	0.913	0.968	0.990	0.997	
195.	0.449	0.665	0.835	0.935	0.979	0.994	
AVE =	0.764	0.873	0.942	0.977	0.992	0.998	

TABLE XIV (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.011	0.040	0.114	0.253	0.443	0.636	0.791
115.	0.002	0.009	0.034	0.101	0.231	0.417	0.613
125.	0.000	0.001	0.004	0.016	0.055	0.156	0.338
135.	0.002	0.007	0.028	0.086	0.207	0.388	0.590
145.	0.017	0.058	0.152	0.312	0.508	0.693	0.830
155.	0.041	0.116	0.256	0.447	0.640	0.793	0.893
165.	0.036	0.106	0.240	0.428	0.623	0.781	0.886
175.	0.011	0.041	0.116	0.257	0.448	0.640	0.794
185.	0.001	0.003	0.013	0.046	0.128	0.277	0.476
195.	0.000	0.001	0.003	0.012	0.043	0.124	0.276
AVE =	0.012	0.038	0.096	0.196	0.333	0.490	0.649
	14.	16.	18.	20.	22.	24.	
105.	0.892	0.948	0.977	0.990	0.996	0.998	
115.	0.774	0.881	0.943	0.974	0.989	0.996	
125.	0.571	0.778	0.909	0.971	0.992	0.998	
135.	0.756	0.887	0.955	0.985	0.996	0.999	
145.	0.914	0.960	0.982	0.993	0.997	0.999	
155.	0.949	0.977	0.990	0.996	0.998	0.999	
165.	0.945	0.975	0.989	0.996	0.998	0.999	
175.	0.893	0.949	0.977	0.990	0.996	0.998	
185.	0.675	0.831	0.927	0.974	0.992	0.998	
195.	0.487	0.700	0.859	0.947	0.984	0.996	
AVE =	0.787	0.889	0.951	0.981	0.994	0.998	

TABLE XV
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.014	0.042	0.107	0.223	0.387	0.570
115.	0.001	0.003	0.012	0.037	0.096	0.205	0.364
125.	0.000	0.001	0.002	0.006	0.020	0.059	0.149
135.	0.001	0.003	0.010	0.031	0.083	0.185	0.341
145.	0.006	0.020	0.058	0.139	0.272	0.447	0.628
155.	0.014	0.043	0.108	0.226	0.391	0.574	0.736
165.	0.013	0.039	0.100	0.212	0.374	0.557	0.722
175.	0.004	0.014	0.043	0.109	0.226	0.391	0.574
185.	0.000	0.001	0.005	0.016	0.048	0.119	0.246
195.	0.000	0.000	0.001	0.005	0.015	0.046	0.118
AVE =	0.004	0.014	0.038	0.089	0.175	0.297	0.445
		14.		18.	20.	22.	24.
105.	0.733	0.852	0.925	0.965	0.984	0.993	
115.	0.547	0.714	0.639	0.918	0.961	0.983	
125.	0.308	0.527	0.729	0.879	0.957	0.987	
135.	0.530	0.712	0.851	0.936	0.977	0.993	
145.	0.777	0.880	0.941	0.973	0.988	0.995	
155.	0.854	0.926	0.965	0.985	0.993	0.997	
165.	0.844	0.921	0.963	0.983	0.993	0.997	
175.	0.736	0.854	0.926	0.966	0.985	0.994	
185.	0.422	0.616	0.785	0.901	0.962	0.988	
195.	0.249	0.438	0.646	0.819	0.925	0.975	
AVE =	0.600	0.743	0.857	0.932	0.973	0.990	

TABLE XV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$T_1 = 1/3268$

$T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.018	0.054	0.131	0.263	0.438	0.621
115.	0.001	0.004	0.015	0.047	0.118	0.243	0.414
125.	0.000	0.001	0.002	0.008	0.025	0.075	0.182
135.	0.001	0.004	0.013	0.040	0.104	0.221	0.391
145.	0.008	0.026	0.073	0.168	0.317	0.499	0.675
155.	0.018	0.055	0.133	0.266	0.442	0.624	0.776
165.	0.017	0.050	0.123	0.251	0.424	0.688	0.763
175.	0.005	0.019	0.055	0.134	0.267	0.443	0.625
185.	0.001	0.002	0.006	0.021	0.061	0.146	0.289
195.	0.000	0.001	0.002	0.006	0.020	0.059	0.145
AVE *	0.006	0.018	0.048	0.107	0.284	0.336	0.488
	14.	16.	18.	20.	22.	24.	
105.	0.773	0.878	0.940	0.972	0.988	0.995	
115.	0.598	0.756	0.867	0.934	0.970	0.987	
125.	0.360	0.581	0.779	0.908	0.969	0.992	
135.	0.583	0.757	0.881	0.952	0.984	0.995	
145.	0.813	0.903	0.950	0.979	0.991	0.996	
155.	0.880	0.941	0.973	0.988	0.995	0.998	
165.	0.872	0.936	0.971	0.987	0.994	0.998	
175.	0.776	0.880	0.941	0.973	0.988	0.995	
185.	0.475	0.668	0.825	0.924	0.973	0.992	
195.	0.294	0.495	0.780	0.856	0.945	0.983	
AVE *	0.643	0.780	0.883	0.947	0.980	0.993	

TABLE XV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$T_1 = 1/3268$

$T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.010	0.035	0.107	0.252	0.469	0.696	0.864
115.	0.002	0.008	0.030	0.093	0.228	0.438	0.668
125.	0.000	0.001	0.004	0.014	0.049	0.146	0.337
135.	0.002	0.006	0.025	0.079	0.202	0.403	0.639
145.	0.015	0.052	0.145	0.317	0.545	0.759	0.900
155.	0.036	0.108	0.256	0.473	0.699	0.866	0.953
165.	0.032	0.099	0.238	0.450	0.680	0.854	0.947
175.	0.010	0.036	0.109	0.257	0.474	0.700	0.866
185.	0.001	0.003	0.011	0.041	0.121	0.278	0.504
195.	0.000	0.001	0.003	0.011	0.038	0.115	0.274
AVE =	0.011	0.035	0.093	0.199	0.351	0.525	0.695
	14.	16.	18.	20.	22.	24.	
105.	0.952	0.986	0.997	0.999	1.000	1.000	
115.	0.846	0.944	0.984	0.996	0.999	1.000	
125.	0.598	0.828	0.952	0.992	0.999	1.000	
135.	0.833	0.944	0.987	0.998	1.000	1.000	
145.	0.967	0.991	0.998	1.000	1.000	1.000	
155.	0.987	0.997	0.999	1.000	1.000	1.000	
165.	0.985	0.996	0.999	1.000	1.000	1.000	
175.	0.953	0.987	0.997	0.999	1.000	1.000	
185.	0.734	0.895	0.971	0.994	0.999	1.000	
195.	0.511	0.752	0.913	0.980	0.997	1.000	
AVE =	0.837	0.932	0.980	0.996	0.999	1.000	

TABLE XV (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$$T_1 = 1/3268$$

$$T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.012	0.043	0.124	0.285	0.510	0.732	0.886
115.	0.003	0.010	0.036	0.110	0.259	0.478	0.705
125.	0.000	0.001	0.004	0.017	0.059	0.170	0.376
135.	0.002	0.008	0.030	0.093	0.230	0.443	0.679
145.	0.018	0.062	0.168	0.353	0.586	0.791	0.918
155.	0.043	0.127	0.288	0.514	0.735	0.888	0.962
165.	0.039	0.116	0.269	0.491	0.716	0.877	0.958
175.	0.012	0.044	0.127	0.289	0.515	0.736	0.888
185.	0.001	0.004	0.014	0.049	0.140	0.312	0.546
195.	0.000	0.001	0.003	0.013	0.046	0.135	0.389
AVE =	0.013	0.041	0.106	0.281	0.380	0.556	0.783
	14.	16.	18.	20.	22.	24.	
105.	0.961	0.989	0.998	0.999	1.000	1.000	
115.	0.878	0.955	0.987	0.997	0.999	1.000	
125.	0.643	0.859	0.964	0.994	0.999	1.000	
135.	0.860	0.956	0.990	0.998	1.000	1.000	
145.	0.974	0.993	0.999	1.000	1.000	1.000	
155.	0.990	0.998	1.000	1.000	1.000	1.000	
165.	0.988	0.997	0.999	1.000	1.000	1.000	
175.	0.962	0.990	0.998	1.000	1.000	1.000	
185.	0.769	0.914	0.978	0.996	1.000	1.000	
195.	0.555	0.788	0.931	0.986	0.998	1.000	
AVE =	0.857	0.944	0.984	0.997	1.000	1.000	

TABLE XVI
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/3268$

$T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.014	0.043	0.110	0.232	0.409	0.609
115.	0.001	0.004	0.012	0.038	0.098	0.212	0.383
125.	0.000	0.001	0.002	0.006	0.020	0.060	0.153
135.	0.001	0.003	0.010	0.032	0.085	0.191	0.358
145.	0.006	0.021	0.060	0.143	0.284	0.474	0.671
155.	0.015	0.044	0.111	0.234	0.412	0.612	0.786
165.	0.013	0.046	0.103	0.220	0.394	0.594	0.772
175.	0.004	0.015	0.044	0.112	0.235	0.413	0.613
185.	0.001	0.001	0.005	0.017	0.049	0.123	0.255
195.	0.000	0.001	0.001	0.005	0.016	0.047	0.121
AVE =	0.005	0.014	0.039	0.092	0.183	0.314	0.472
	14.	16.	18.	20.	22.	24.	
105.	0.763	0.980	0.961	0.987	0.996	0.999	
115.	0.583	0.763	0.888	0.956	0.985	0.996	
125.	0.319	0.545	0.766	0.913	0.977	0.996	
135.	0.563	0.758	0.925	0.966	0.992	0.998	
145.	0.828	0.925	0.972	0.991	0.998	0.999	
155.	0.981	0.962	0.987	0.996	0.999	1.000	
165.	0.893	0.958	0.986	0.996	0.999	1.000	
175.	0.786	0.902	0.962	0.987	0.996	0.999	
185.	0.445	0.654	0.831	0.938	0.983	0.997	
195.	0.258	0.468	0.683	0.868	0.955	0.990	
AVE =	0.636	0.783	0.893	0.959	0.988	0.997	

TABLE XVI (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.018	0.055	0.135	0.274	0.463	0.663
115.	0.001	0.005	0.016	0.048	0.121	0.252	0.437
125.	0.000	0.001	0.002	0.008	0.026	0.076	0.187
135.	0.001	0.004	0.013	0.041	0.106	0.229	0.411
145.	0.008	0.027	0.075	0.174	0.332	0.530	0.721
155.	0.019	0.056	0.137	0.277	0.467	0.666	0.826
165.	0.017	0.051	0.127	0.261	0.448	0.648	0.813
175.	0.006	0.019	0.056	0.137	0.278	0.468	0.667
185.	0.001	0.002	0.006	0.021	0.062	0.150	0.301
195.	0.000	0.001	0.002	0.006	0.020	0.060	0.149
AVE =	0.006	0.018	0.049	0.111	0.213	0.354	0.517
	14.	16.	18.	20.	22.	24.	
105.	0.823	0.923	0.971	0.991	0.997	0.999	
115.	0.638	0.806	0.913	0.967	0.990	0.997	
125.	0.374	0.609	0.817	0.939	0.985	0.997	
135.	0.620	0.804	0.922	0.977	0.995	0.999	
145.	0.863	0.943	0.980	0.994	0.998	1.000	
155.	0.924	0.972	0.991	0.998	0.999	1.000	
165.	0.917	0.969	0.990	0.997	0.999	1.000	
175.	0.826	0.924	0.972	0.991	0.998	0.999	
185.	0.502	0.710	0.869	0.956	0.989	0.998	
195.	0.306	0.521	0.739	0.895	0.970	0.994	
AVE =	0.679	0.818	0.917	0.970	0.992	0.998	

TABLE XVI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$$T_1 = 1/3268$$

$$T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.010	0.036	0.108	0.258	0.485	0.726	0.896
115.	0.002	0.008	0.031	0.095	0.234	0.453	0.697
125.	0.000	0.001	0.004	0.014	0.050	0.148	0.345
135.	0.002	0.007	0.023	0.059	0.206	0.416	0.666
145.	0.015	0.053	0.148	0.326	0.567	0.793	0.930
155.	0.037	0.110	0.262	0.498	0.730	0.898	0.973
165.	0.033	0.100	0.244	0.466	0.710	0.887	0.969
175.	0.010	0.037	0.111	0.263	0.491	0.731	0.899
185.	0.001	0.003	0.012	0.042	0.123	0.285	0.523
195.	0.000	0.001	0.003	0.011	0.039	0.117	0.281
AVE *	0.011	0.036	0.095	0.204	0.363	0.545	0.718
	14.	16.	18.	20.	22.	24.	
105.	0.973	0.995	0.999	1.000	1.000	1.000	
115.	0.880	0.967	0.993	0.999	1.000	1.000	
125.	0.618	0.856	0.971	0.997	1.000	1.000	
135.	0.867	0.966	0.995	1.000	1.000	1.000	
145.	0.983	0.997	1.000	1.000	1.000	1.000	
155.	0.995	0.999	1.000	1.000	1.000	1.000	
165.	0.994	0.999	1.000	1.000	1.000	1.000	
175.	0.973	0.995	0.999	1.000	1.000	1.000	
185.	0.765	0.924	0.985	0.998	1.000	1.000	
195.	0.528	0.782	0.939	0.991	0.999	1.000	
AVE *	0.858	0.948	0.988	0.998	1.000	1.000	

TABLE XVI (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$$T_1 = 1/3268$$

$$T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.812	0.843	0.126	0.292	0.528	0.764	0.916
115.	0.803	0.819	0.037	0.111	0.265	0.495	0.736
125.	0.806	0.801	0.084	0.017	0.060	0.173	0.387
135.	0.802	0.808	0.336	0.695	0.235	0.458	0.707
145.	0.819	0.863	0.171	0.364	0.619	0.825	0.945
155.	0.844	0.129	0.296	0.533	0.767	0.916	0.980
165.	0.839	0.117	0.276	0.509	0.748	0.906	0.977
175.	0.812	0.844	0.129	0.296	0.534	0.768	0.919
185.	0.801	0.804	0.014	0.050	0.143	0.321	0.567
195.	0.800	0.801	0.003	0.013	0.047	0.137	0.317
AVE =	0.813	0.842	0.109	0.226	0.394	0.577	0.745
	14.	16.	18.	20.	22.	24.	
105.	0.979	0.994	0.999	1.000	1.000	1.000	
115.	0.982	0.975	0.995	0.999	1.000	1.000	
125.	0.665	0.886	0.979	0.998	1.000	1.000	
135.	0.892	0.973	0.997	1.000	1.000	1.000	
145.	0.988	0.998	1.000	1.000	1.000	1.000	
155.	0.996	1.000	1.000	1.000	1.000	1.000	
165.	0.996	0.999	1.000	1.000	1.000	1.000	
175.	0.988	0.994	1.000	1.000	1.000	1.000	
185.	0.881	0.941	0.998	0.999	1.000	1.000	
195.	0.574	0.818	0.954	0.994	1.000	1.000	
AVE =	0.877	0.958	0.991	0.999	1.000	1.000	

TABLE XVII
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010$$

$$T_2 = 1/2645$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE I

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.018	0.056	0.143	0.296
115.	0.009	0.030	0.051	0.176	0.311	0.453	0.607
125.	0.031	0.084	0.180	0.316	0.469	0.612	0.729
135.	0.026	0.071	0.160	0.290	0.442	0.588	0.711
145.	0.004	0.015	0.046	0.114	0.227	0.373	0.525
155.	0.006	0.001	0.002	0.006	0.023	0.072	0.181
165.	0.002	0.006	0.019	0.037	0.135	0.256	0.405
175.	0.010	0.032	0.086	0.184	0.321	0.474	0.616
185.	0.026	0.071	0.160	0.291	0.443	0.591	0.717
195.	0.035	0.095	0.207	0.371	0.557	0.726	0.849
AVE =	0.014	0.041	0.095	0.182	0.298	0.430	0.564
	14.	16.	18.	20.	22.	24.	
105.	0.492	0.681	0.824	0.912	0.959	0.962	
115.	0.726	0.316	0.882	0.927	0.958	0.978	
125.	0.818	0.880	0.922	0.950	0.968	0.980	
135.	0.804	0.870	0.916	0.946	0.965	0.978	
145.	0.560	0.768	0.849	0.907	0.947	0.972	
155.	0.357	0.563	0.741	0.864	0.935	0.971	
165.	0.555	0.684	0.785	0.857	0.907	0.941	
175.	0.733	0.820	0.882	0.923	0.951	0.969	
185.	0.817	0.890	0.939	0.969	0.985	0.993	
195.	0.925	0.965	0.985	0.993	0.997	0.999	
AVE =	0.689	0.794	0.872	0.925	0.957	0.976	

TABLE XVII (Continued)

DETECTION PROBABILITY FOR COHERENT NTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$

$T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.002	0.004	0.002	0.071	0.176	0.347
115.	0.012	0.028	0.101	0.209	0.354	0.366	0.646
125.	0.048	0.164	0.214	0.268	0.514	0.653	0.759
135.	0.033	0.089	0.171	0.338	0.487	0.628	0.742
145.	0.006	0.020	0.059	0.148	0.266	0.416	0.568
155.	0.000	0.001	0.002	0.003	0.020	0.092	0.201
165.	0.002	0.007	0.026	0.038	0.163	0.291	0.458
175.	0.013	0.042	0.170	0.218	0.345	0.518	0.655
185.	0.033	0.089	0.192	0.331	0.488	0.631	0.758
195.	0.045	0.116	0.217	0.347	0.489	0.767	0.876
AVE =	0.018	0.051	0.118	0.218	0.335	0.467	0.681
	14.	16.	18.	20.	22.	24.	
105.	0.562	0.580	0.656	0.938	0.968	0.986	
115.	0.737	0.839	0.897	0.938	0.969	0.982	
125.	0.839	0.875	0.932	0.956	0.972	0.982	
135.	0.827	0.886	0.924	0.953	0.978	0.981	
145.	0.594	0.798	0.869	0.921	0.956	0.977	
155.	0.414	0.619	0.784	0.898	0.949	0.977	
165.	0.597	0.718	0.816	0.875	0.919	0.949	
175.	0.763	0.842	0.896	0.933	0.957	0.972	
185.	0.841	0.907	0.958	0.975	0.988	0.993	
195.	0.940	0.973	0.985	0.995	0.998	0.999	
AVE =	0.722	0.820	0.891	0.937	0.964	0.943	

TABLE XVII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	8.	9.	10.	11.	12.	13.	14.
105.	0.001	0.003	0.012	0.045	0.141	0.335	0.593
115.	0.023	0.078	0.200	0.391	0.600	0.772	0.883
125.	0.001	0.207	0.399	0.608	0.777	0.956	0.947
135.	0.066	0.179	0.362	0.572	0.751	0.871	0.939
145.	0.010	0.039	0.119	0.273	0.479	0.678	0.825
155.	0.000	0.001	0.004	0.015	0.058	0.181	0.410
165.	0.203	0.814	0.851	0.145	0.314	0.524	0.714
175.	0.025	0.084	0.212	0.406	0.614	0.782	0.889
185.	0.067	0.179	0.363	0.573	0.753	0.873	0.942
195.	0.091	0.232	0.449	0.684	0.860	0.952	0.987
AVE =	0.007	0.101	0.217	0.371	0.535	0.685	0.813
	15.	16.	18.	20.	22.	24.	
105.	0.812	0.934	0.982	0.996	0.999	1.000	
115.	0.945	0.976	0.990	0.997	0.999	1.000	
125.	0.976	0.998	0.996	0.998	0.999	1.000	
135.	0.973	0.983	0.995	0.998	0.999	1.000	
145.	0.914	0.962	0.984	0.994	0.998	1.000	
155.	0.676	0.868	0.959	0.998	0.999	1.000	
165.	0.846	0.926	0.967	0.966	0.994	0.998	
175.	0.948	0.977	0.990	0.996	0.998	0.999	
185.	0.977	0.992	0.998	0.999	1.000	1.000	
195.	0.997	0.999	1.000	1.000	1.000	1.000	
AVE =	0.987	0.961	0.956	0.995	0.998	0.999	

TABLE XVII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.004	0.014	0.054	0.165	0.376	0.637
115.	0.028	0.092	0.228	0.429	0.636	0.797	0.899
125.	0.096	0.235	0.437	0.643	0.802	0.901	0.954
135.	0.079	0.205	0.399	0.609	0.779	0.888	0.947
145.	0.013	0.047	0.138	0.306	0.517	0.710	0.846
155.	0.000	0.001	0.005	0.019	0.070	0.211	0.456
165.	0.004	0.017	0.061	0.168	0.349	0.561	0.744
175.	0.031	0.099	0.241	0.444	0.650	0.807	0.904
185.	0.079	0.205	0.400	0.610	0.780	0.890	0.951
195.	0.108	0.263	0.491	0.721	0.883	0.962	0.990
AVE =	0.044	0.117	0.241	0.480	0.563	0.710	0.833
	14.	16.	18.	20.	22.	24.	
105.	0.842	0.948	0.986	0.997	0.999	1.000	
115.	0.953	0.980	0.992	0.997	0.999	1.000	
125.	0.980	0.992	0.996	0.999	0.999	1.000	
135.	0.977	0.990	0.996	0.998	0.999	1.000	
145.	0.926	0.967	0.987	0.995	0.999	1.000	
155.	0.718	0.892	0.968	0.992	0.998	1.000	
165.	0.867	0.937	0.972	0.988	0.995	0.998	
175.	0.956	0.981	0.992	0.997	0.999	0.999	
185.	0.981	0.994	0.998	1.000	1.000	1.000	
195.	0.998	1.000	1.000	1.000	1.000	1.000	
AVE =	0.920	0.968	0.989	0.996	0.999	1.000	

TABLE XVIII
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.010	0.031	0.083	0.180	0.316	0.469	0.612
115.	0.002	0.008	0.027	0.074	0.165	0.297	0.449
125.	0.000	0.001	0.004	0.014	0.044	0.117	0.252
135.	0.002	0.007	0.022	0.064	0.148	0.277	0.435
145.	0.014	0.044	0.110	0.221	0.366	0.518	0.653
155.	0.032	0.085	0.182	0.319	0.472	0.614	0.731
165.	0.029	0.078	0.171	0.305	0.457	0.602	0.721
175.	0.010	0.032	0.085	0.183	0.320	0.472	0.615
185.	0.001	0.003	0.011	0.036	0.094	0.198	0.345
195.	0.000	0.001	0.003	0.011	0.034	0.092	0.201
AVE =	0.010	0.029	0.070	0.141	0.241	0.365	0.561
	14.	16.	18.	20.	22.	24.	
105.	0.729	0.818	0.880	0.922	0.950	0.968	
115.	0.594	0.716	0.808	0.874	0.919	0.950	
125.	0.438	0.632	0.789	0.891	0.948	0.977	
135.	0.597	0.740	0.848	0.920	0.961	0.982	
145.	0.761	0.841	0.896	0.934	0.959	0.976	
155.	0.819	0.881	0.923	0.950	0.968	0.980	
165.	0.812	0.876	0.919	0.948	0.967	0.979	
175.	0.732	0.819	0.881	0.924	0.952	0.971	
185.	0.512	0.672	0.802	0.892	0.946	0.975	
195.	0.361	0.547	0.716	0.842	0.921	0.963	
AVE =	0.636	0.754	0.846	0.910	0.949	0.972	

TABLE XVIII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.012	0.040	0.104	0.214	0.360	0.513	0.650
115.	0.003	0.011	0.035	0.093	0.197	0.339	0.493
125.	0.000	0.001	0.005	0.018	0.056	0.145	0.298
135.	0.002	0.009	0.029	0.081	0.179	0.320	0.483
145.	0.019	0.056	0.135	0.259	0.410	0.561	0.689
155.	0.041	0.105	0.217	0.362	0.516	0.653	0.761
165.	0.037	0.097	0.204	0.348	0.502	0.641	0.752
175.	0.013	0.041	0.106	0.217	0.363	0.516	0.653
185.	0.001	0.004	0.015	0.046	0.116	0.235	0.391
195.	0.000	0.001	0.004	0.014	0.044	0.114	0.240
AVE =	0.013	0.037	0.085	0.165	0.274	0.404	0.541
	14.	16.	18.	20.	22.	24.	
105.	0.759	0.839	0.895	0.932	0.956	0.972	
115.	0.634	0.747	0.831	0.890	0.930	0.957	
125.	0.494	0.683	0.825	0.913	0.959	0.982	
135.	0.641	0.775	0.873	0.935	0.969	0.986	
145.	0.789	0.860	0.909	0.942	0.965	0.980	
155.	0.840	0.896	0.933	0.957	0.972	0.983	
165.	0.804	0.891	0.930	0.955	0.971	0.982	
175.	0.762	0.841	0.896	0.934	0.959	0.976	
185.	0.560	0.713	0.833	0.912	0.957	0.981	
195.	0.412	0.599	0.759	0.871	0.937	0.971	
AVE =	0.672	0.784	0.868	0.924	0.958	0.977	

TABLE XVIII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.024	0.031	0.206	0.399	0.608	0.777	0.884
115.	0.005	0.020	0.070	0.185	0.371	0.582	0.758
125.	0.001	0.002	0.009	0.034	0.111	0.279	0.526
135.	0.004	0.016	0.058	0.162	0.340	0.555	0.747
145.	0.037	0.113	0.264	0.469	0.669	0.819	0.910
155.	0.082	0.209	0.403	0.611	0.779	0.888	0.947
165.	0.074	0.194	0.383	0.593	0.766	0.880	0.943
175.	0.025	0.083	0.210	0.404	0.612	0.780	0.888
185.	0.002	0.007	0.029	0.092	0.229	0.431	0.646
195.	0.000	0.002	0.007	0.026	0.087	0.224	0.438
AVE =	0.025	0.073	0.164	0.298	0.457	0.621	0.769
	14.	16.	18.	20.	22.	24.	
105.	0.947	0.976	0.990	0.996	0.998	0.999	
115.	0.875	0.941	0.974	0.989	0.995	0.998	
125.	0.761	0.909	0.973	0.993	0.999	1.000	
135.	0.881	0.954	0.986	0.996	0.999	1.000	
145.	0.959	0.982	0.992	0.997	0.999	1.000	
155.	0.977	0.990	0.996	0.998	0.999	1.000	
165.	0.975	0.989	0.995	0.998	0.999	1.000	
175.	0.948	0.977	0.990	0.996	0.998	0.999	
185.	0.819	0.925	0.975	0.993	0.998	1.000	
195.	0.672	0.852	0.948	0.987	0.997	0.999	
AVE =	0.881	0.950	0.982	0.994	0.998	0.999	

TABLE XVIII (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-5}$$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.030	0.096	0.235	0.437	0.643	0.802	0.901
115.	0.006	0.025	0.083	0.212	0.408	0.618	0.785
125.	0.001	0.003	0.011	0.041	0.131	0.317	0.571
135.	0.005	0.020	0.070	0.187	0.376	0.593	0.777
145.	0.045	0.132	0.296	0.507	0.702	0.841	0.923
155.	0.097	0.238	0.441	0.647	0.805	0.903	0.955
165.	0.088	0.222	0.420	0.628	0.792	0.896	0.951
175.	0.030	0.098	0.239	0.442	0.647	0.805	0.903
185.	0.002	0.009	0.035	0.109	0.259	0.470	0.682
195.	0.001	0.002	0.008	0.032	0.103	0.255	0.480
AVE =	0.030	0.084	0.184	0.324	0.487	0.650	0.793
	14.	16.	18.	20.	22.	24.	
105.	0.954	0.980	0.992	0.996	0.999	0.999	
115.	0.891	0.949	0.978	0.991	0.996	0.999	
125.	0.796	0.926	0.979	0.995	0.999	1.000	
135.	0.899	0.963	0.989	0.997	0.999	1.000	
145.	0.965	0.985	0.994	0.998	0.999	1.000	
155.	0.980	0.992	0.997	0.999	0.999	1.000	
165.	0.979	0.991	0.996	0.998	0.999	1.000	
175.	0.955	0.980	0.992	0.997	0.999	1.000	
185.	0.844	0.938	0.980	0.995	0.999	1.000	
195.	0.710	0.875	0.958	0.989	0.997	0.999	
AVE =	0.897	0.958	0.985	0.995	0.999	1.000	

TABLE XIX
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 101,1

V	PD1A	PD1B	PDS
105	0.557	0.711	0.872
115	0.045	0.901	0.905
125	0.000	0.937	0.937
135	0.000	0.932	0.932
145	0.052	0.872	0.879
155	0.568	0.552	0.806
165	0.823	0.000	0.823
175	0.904	0.000	0.904
185	0.932	0.340	0.955
195	0.939	0.832	0.990

AVERAGE PROB. = 0.900

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 42,1

V	PD1A	PD1B	PDS
105	0.267	0.454	0.600
115	0.003	0.780	0.781
125	0.000	0.856	0.856
135	0.000	0.845	0.845
145	0.004	0.724	0.725
155	0.278	0.262	0.467
165	0.632	0.000	0.632
175	0.787	0.000	0.787
185	0.846	0.098	0.861
195	0.861	0.649	0.951

AVERAGE PROB. = 0.750

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $= 16.55, 1$

V	PD1A	PD1B	PDS
105	0.055	0.161	0.207
115	0.000	0.543	0.543
125	0.000	0.680	0.680
135	0.000	0.659	0.659
145	0.000	0.455	0.455
155	0.060	0.053	0.110
165	0.332	0.000	0.332
175	0.554	0.000	0.554
185	0.659	0.010	0.662
195	0.688	0.353	0.798

$$\text{AVERAGE PROB.} = 0.500$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $= 86.5, 2$

V	PD2A	PD2B	PDS
105	0.555	0.710	0.871
115	0.041	0.901	0.905
125	0.000	0.937	0.937
135	0.000	0.932	0.932
145	0.048	0.872	0.879
155	0.566	0.550	0.805
165	0.823	0.000	0.823
175	0.904	0.000	0.904
185	0.932	0.335	0.955
195	0.939	0.832	0.993

$$\text{AVERAGE PROB.} = 0.900$$

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010$$

$$T_2 = 1/2645$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $\approx 36.2, 2$

V	PD2A	PD2B	PDS
105	0.264	0.453	0.597
115	0.003	0.781	0.782
125	0.000	0.857	0.857
135	0.000	0.846	0.846
145	0.004	0.725	0.726
155	0.275	0.259	0.463
165	0.632	0.000	0.632
175	0.788	0.000	0.788
185	0.846	0.094	0.861
195	0.852	0.650	0.952

AVERAGE PROB. ≈ 0.750

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $\approx 14.35, 2$

V	PD2A	PD2B	PDS
105	0.052	0.158	0.202
115	0.000	0.545	0.545
125	0.000	0.682	0.682
135	0.000	0.661	0.661
145	0.000	0.456	0.456
155	0.057	0.050	0.104
165	0.332	0.000	0.332
175	0.556	0.000	0.556
185	0.661	0.008	0.664
195	0.691	0.353	0.800

AVERAGE PROB. ≈ 0.502

TABLE XIX (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 30,3

V	PD3A	PD3B	PDS
105	0.402	0.657	0.795
115	0.003	0.942	0.942
125	0.000	0.975	0.975
135	0.000	0.971	0.971
145	0.004	0.909	0.909
155	0.419	0.394	0.648
165	0.840	0.000	0.840
175	0.945	0.000	0.945
185	0.971	0.138	0.975
195	0.977	0.855	0.997

AVERAGE PROB. = 0.900

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 15.65,3

V	PD3A	PD3B	PDS
105	0.140	0.360	0.449
115	0.000	0.836	0.836
125	0.000	0.923	0.923
135	0.000	0.912	0.912
145	0.000	0.760	0.760
155	0.150	0.135	0.265
165	0.624	0.000	0.624
175	0.844	0.000	0.844
185	0.912	0.025	0.914
195	0.927	0.650	0.974

AVERAGE PROB. = 0.750

TABLE XIX (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 7.2, 3

V	PD3A	PD3B	PDS
105	0.017	0.085	0.100
115	0.000	0.561	0.561
125	0.000	0.751	0.751
135	0.000	0.723	0.723
145	0.000	0.434	0.434
155	0.019	0.016	0.034
165	0.268	0.000	0.268
175	0.576	0.000	0.576
185	0.723	0.002	0.724
195	0.762	0.296	0.832

AVERAGE PROB. = 0.500

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 27.8, 4

V	PD4A	PD4B	PDS
105	0.399	0.656	0.794
115	0.003	0.943	0.943
125	0.000	0.975	0.975
135	0.000	0.972	0.972
145	0.003	0.910	0.910
155	0.416	0.391	0.645
165	0.841	0.000	0.841
175	0.946	0.000	0.946
185	0.972	0.134	0.975
195	0.977	0.855	0.997

AVERAGE PROB. = 0.900

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/4010 \quad T_2 = 1/2645$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $\approx 14.55, 4$

V	PD4A	PD4B	PDS
105	0.136	0.358	0.445
115	0.000	0.838	0.838
125	0.000	0.924	0.924
135	0.000	0.913	0.913
145	0.000	0.761	0.761
155	0.147	0.131	0.259
165	0.624	0.000	0.624
175	0.846	0.000	0.846
185	0.913	0.023	0.915
195	0.928	0.651	0.975

$$\text{AVERAGE PROB.} = 0.750$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $\approx 6.7, 4$

V	PD4A	PD4B	PDS
105	0.015	0.082	0.096
115	0.000	0.562	0.562
125	0.000	0.753	0.753
135	0.000	0.725	0.725
145	0.000	0.433	0.433
155	0.017	0.014	0.031
165	0.266	0.000	0.266
175	0.577	0.000	0.577
185	0.725	0.601	0.725
195	0.764	0.293	0.833

$$\text{AVERAGE PROB.} = 0.509$$

TABLE XX
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 118.1

V	PDIA	PDIB	PDS
105	0.000	0.916	0.916
115	0.003	0.863	0.863
125	0.543	0.728	0.876
135	0.853	0.379	0.909
145	0.927	0.010	0.928
155	0.946	0.000	0.946
165	0.944	0.000	0.944
175	0.917	0.006	0.917
185	0.813	0.348	0.878
195	0.377	0.714	0.822

AVERAGE PROB. = 0.900

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 50.7.1

V	PDIA	PDIB	PDS
105	0.000	0.817	0.817
115	0.000	0.714	0.714
125	0.263	0.490	0.624
135	0.696	0.129	0.735
145	0.840	0.001	0.840
155	0.880	0.000	0.880
165	0.875	0.000	0.875
175	0.818	0.000	0.818
185	0.624	0.109	0.665
195	0.128	0.469	0.537

AVERAGE PROB. = 0.750

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $= 20.55, 1$

V	PD1A	PD1B	PDS
105	0.000	0.614	0.614
115	0.000	0.449	0.449
125	0.057	0.197	0.243
135	0.424	0.016	0.433
145	0.656	0.000	0.656
155	0.733	0.000	0.733
165	0.724	0.000	0.724
175	0.617	0.000	0.617
185	0.333	0.012	0.341
195	0.016	0.180	0.183

AVERAGE PROB. = 0.500

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $= 101.3, 2$

V	PD2A	PD2B	PDS
105	0.000	0.916	0.916
115	0.002	0.863	0.864
125	0.542	0.728	0.875
135	0.854	0.376	0.909
145	0.927	0.009	0.928
155	0.947	0.000	0.947
165	0.944	0.000	0.944
175	0.917	0.005	0.917
185	0.813	0.344	0.878
195	0.374	0.714	0.821

AVERAGE PROB. = 0.900

TABLE XX (Continued)
DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers Average

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950 \\ P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 = 43.62

V	PD2A	PD2B	PDS
105	0.000	0.617	0.817
115	0.000	0.714	0.714
125	0.268	0.408	0.681
135	0.696	0.124	0.734
145	0.848	0.608	0.848
155	0.881	0.000	0.881
165	0.876	0.000	0.876
175	0.819	0.000	0.819
185	0.624	0.185	0.664
195	0.123	0.468	0.533

AVERAGE PROB. = 0.750

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 = 17.62

V	PD2A	PD2B	PDS
105	0.000	0.616	0.616
115	0.000	0.459	0.459
125	0.054	0.194	0.238
135	0.424	0.015	0.433
145	0.658	0.000	0.658
155	0.735	0.000	0.735
165	0.786	0.000	0.786
175	0.619	0.000	0.619
185	0.332	0.011	0.339
195	0.014	0.178	0.189

AVERAGE PROB. = 0.500

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268$$

$$T_2 = 1/4950$$

$$P_F = 10^{-5}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 = 34.6,3

V	PD3A	PD3B	PDS
105	0.000	0.956	0.956
115	0.000	0.895	0.895
125	0.375	0.681	0.801
135	0.802	0.171	0.902
145	0.966	0.000	0.966
155	0.981	0.000	0.981
165	0.979	0.000	0.979
175	0.957	0.000	0.957
185	0.822	0.142	0.847
195	0.139	0.657	0.715

AVERAGE PROB. = 0.900

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 = 18.6,3

V	PD3A	PD3B	PDS
105	0.000	0.877	0.877
115	0.000	0.740	0.740
125	0.132	0.403	0.482
135	0.713	0.037	0.724
145	0.903	0.000	0.903
155	0.943	0.000	0.943
165	0.938	0.000	0.938
175	0.879	0.000	0.879
185	0.606	0.028	0.617
195	0.036	0.374	0.397

AVERAGE PROB. = 0.750

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268$$

$$T_2 = 1/4950$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $= 8.95, 3$

V	PD3A	PD3B	PDS
105	0.000	0.662	0.662
115	0.000	0.427	0.427
125	0.018	0.117	0.133
135	0.391	0.003	0.393
145	0.719	0.000	0.719
155	0.818	0.000	0.818
165	0.806	0.000	0.806
175	0.666	0.000	0.666
185	0.269	0.002	0.271
195	0.003	0.102	0.105

AVERAGE PROB. = 0.500

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 $= 32, 4$

V	PD4A	PD4B	PDS
105	0.000	0.956	0.956
115	0.000	0.895	0.895
125	0.371	0.680	0.799
135	0.882	0.166	0.902
145	0.967	0.000	0.967
155	0.981	0.000	0.981
165	0.980	0.000	0.980
175	0.957	0.000	0.957
185	0.823	0.137	0.847
195	0.164	0.556	0.712

AVERAGE PROB. = 0.900

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$$T_1 = 1/3268 \quad T_2 = 1/4950$$

$$P_F = 10^{-6}$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 = 17, 3, 4

V	PD4A	PD4B	PDS
105	0.000	0.879	0.879
115	0.000	0.741	0.741
125	0.128	0.402	0.479
135	0.715	0.035	0.725
145	0.905	0.060	0.905
155	0.944	0.000	0.944
165	0.940	0.000	0.940
175	0.881	0.000	0.881
185	0.606	0.026	0.617
195	0.034	0.373	0.394

$$\text{AVERAGE PROB.} = 0.750$$

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
 = 8, 35, 4

V	PD4A	PD4B	PDS
105	0.000	0.664	0.664
115	0.000	0.427	0.427
125	0.016	0.115	0.129
135	0.391	0.003	0.393
145	0.722	0.000	0.722
155	0.820	0.000	0.820
165	0.809	0.000	0.809
175	0.668	0.000	0.668
185	0.268	0.002	0.269
195	0.003	0.099	0.102

$$\text{AVERAGE PROB.} = 0.560$$

TABLE XXI
 S/N FOR SCAN MODE $P_F = 10^{-4}$
 Comparison Ward - Vannicola

	Probability of Detection				BEAMS
	50%	75%	90%	95%	
Ward	4.4	6.8	9.4	10.9	Center A only
Using Barton	5.8	7.8	9.7	10.7	AUB Position Average
Vannicola Using Appendix B	4.5	7.2	9.8	11.7	Center A only
	5.7	8.0	10.1	11.3	AUB Position Average

TABLE XXII
S/N (DB) FOR 75% DETECTION PROBABILITY

		BEAMS	SCAN	MTI	MTI LOSS
Ward $P_F = 10^{-4}$ Average Velocity	I^2	AUB	7.8	14.8	7.0
	$I^2 + Q^2$	AUB	7.8	11.1	3.3
	I^2	AUBUCUD		14.3	
Vannicola 10^{-4} Average over all T	I^2	AUB	8.0	19.1	11.1
	$I^2 + Q^2$	AUB	8.0	15.0	7.0
Vannicola $P_F = 10^{-5}$ Average over all T	I^2	{ Center }	5.2	14.9	9.7
	$I^2 + Q^2$	{ AUE }	5.2	11.0	5.8
$P_F = 10^{-5}$ Average over all T	I^2	AUE	7.4	17.0	9.6
	$I^2 + Q^2$	AUE	7.4	13.0	5.6
$P_F = 10^{-5}$ $T_1 = 1/4010 \quad T_2 = 1/2645$	I^2	AUB	8.8	19.1	10.3
	$I^2 + Q^2$	AUB	8.8	15.0	6.2
$P_F = 10^{-5}$ $T_1 = 1/4010 \quad T_2 = 1/2645$	I^2	(AUB)U(EUF)	6.7	14.7	8.0
	$I^2 + Q^2$	(AUB)U(EUF)	6.7	11.6	4.9

APPENDIX A

DETECTION OF SLOW FLUCTUATING TARGETS WITH FREQUENCY DIVERSITY CHANNELS

by

Vincent Vannicola

Introduction

In this appendix an exact closed-form expression for the radar detection probability is derived and tabulated for a frequency diversity radar receiver. The receiver model performs post detection integration on all received pulses in all diversity channels. The target model assumed is the slow fluctuating Rayleigh-distributed (Swerling Case I Target) scatterer. Each of the M frequency diverse channels receives N amplitude correlated returns to give a total of NM post square law detection integrations. The tabulated data computed herein falls between the two extreme cases; that for which all the returns are amplitude correlated and that for which each return is independent. The plotted results fall close to the figures obtained through simple empirical relationships.

Returns from radar targets generally fluctuate in amplitude and phase according to some probability density function and some fluctuation rate. If one is to analytically determine the detection probability for a particular type of target in a noise environment, it is necessary that the statistics of target return and noise be known. Although it is not always possible to characterize the actual target return statistics, one can make a good approximation which gives remarkable results for a wide variety of target and noise situations.

The four target cases modeled and evaluated by Swerling^[1] are well known to radar engineers and have met with great acceptance. The situations which these cases cover are of two extremes:

1. That of a slowly fluctuating target where the cross section is random and remains correlated during the scan time. The pulses reflected off such a target are correlated with each other in amplitude during that scan although the pulse-to-pulse phase may be independent.
2. That of a rapidly fluctuating target where the cross section becomes uncorrelated from pulse to pulse. The received amplitude and phase are independent from pulse to pulse. The noise in all four models is zero-mean white Gaussian.

An excellent treatment of these four cases is given by DiFranco and Rubin^[2] wherein the optimum receiver along with its performance is derived and plotted in Signal-to-Noise curves.

For partially correlated received pulses, several papers have been written.

Swerling has developed^[3] a method which is applicable to a large family of probability density functions and for fairly general correlation properties of the signal fluctuations. His method yields the characteristic function of the probability density of sum random variables defined as Y. To obtain p(Y) and p_d with this technique requires computer evaluations.

Swerling^[4] considered the partially correlated case for N = 2 and a Rayleigh amplitude density function. As to be expected, his curves fall between those of the two extremes: zero correlation and complete correlation.

In a recent paper by Barton^[5] an approximate formula is given for determining the signal-to-noise required for a given detection probability when there are N pulses representing n_c independent signal samples. The method is based on a very simple empirical relationship which appears to interpolate between complete correlation and zero correlation from pulse-to-pulse. For the examples tested it is shown that this approach renders remarkably accurate results.

A similar expression involving interpolation methods is given by Swerling [6].

In this appendix, the case of M frequency diverse channels each containing N correlated pulses each with Rayleigh amplitude density function is evaluated. An exact closed-form solution is derived for the output probability density function and the detection probability for a given false alarm probability and signal-to-noise ratio when all MN pulses are square law detected and combined as shown in Figure A-1. Each of the MN pulses has independent Gaussian noise, and each group of N pulses has an independent Gaussian signal giving a total of M independent signals in all MN pulses.

DERIVATION OF PROBABILITY DENSITY FUNCTION

We may start the derivation simply by using the results of DiFranco and Rubin [2]

DETERMINING THE THRESHOLD FOR FALSE ALARM

The output probability density function for no signal present may be written from equation [2] (10.4-17) with MN representing the total number of pulses and the variable Y representing the "convenient modified form" of equation (10.4-4)

$$Y = \sum_{i=1}^{MN} \frac{1}{2} r_i^2 \quad (A-1)$$

$$p(Y; 0) = \frac{Y^{MN-1} e^{-Y}}{(MN-1)!} \quad (A-2)$$

From (A-2) we may write the false alarm probability using [2] (10.4-18a)

$$P_F = \int_{Y_b}^{\infty} p(Y; 0) dY = \int_{Y_b}^{\infty} \frac{Y^{MN-1} e^{-Y}}{(MN-1)!} dY \quad (A-3)$$

This integral has been evaluated by Pachares [7] for $1 \leq MN \leq 150$ and false alarm probabilities equal to 10^{-m} where m is an integer ranging between 1 and 12. Using the Pachares tables, one may obtain threshold Y_b to four decimal places.

DETECTION PROBABILITY

Next the probability of detection is derived. We may start with the characteristic function of the signal out of the N pulse integrator which corresponds to the Swerling Case I given by DiFranco and Rubin [2] in (11.2-23) and is repeated here.

$$\frac{C_{V_i}(\xi) \Lambda_i}{(1 + NA_0^2)} = \frac{(-1)^N}{\left(1 + \frac{1}{1 + NA_0^2} + j\xi\right) (-1 + j\xi)^{N-1}} \quad (A-4)$$

where Λ_i is the variance of the target return signal.

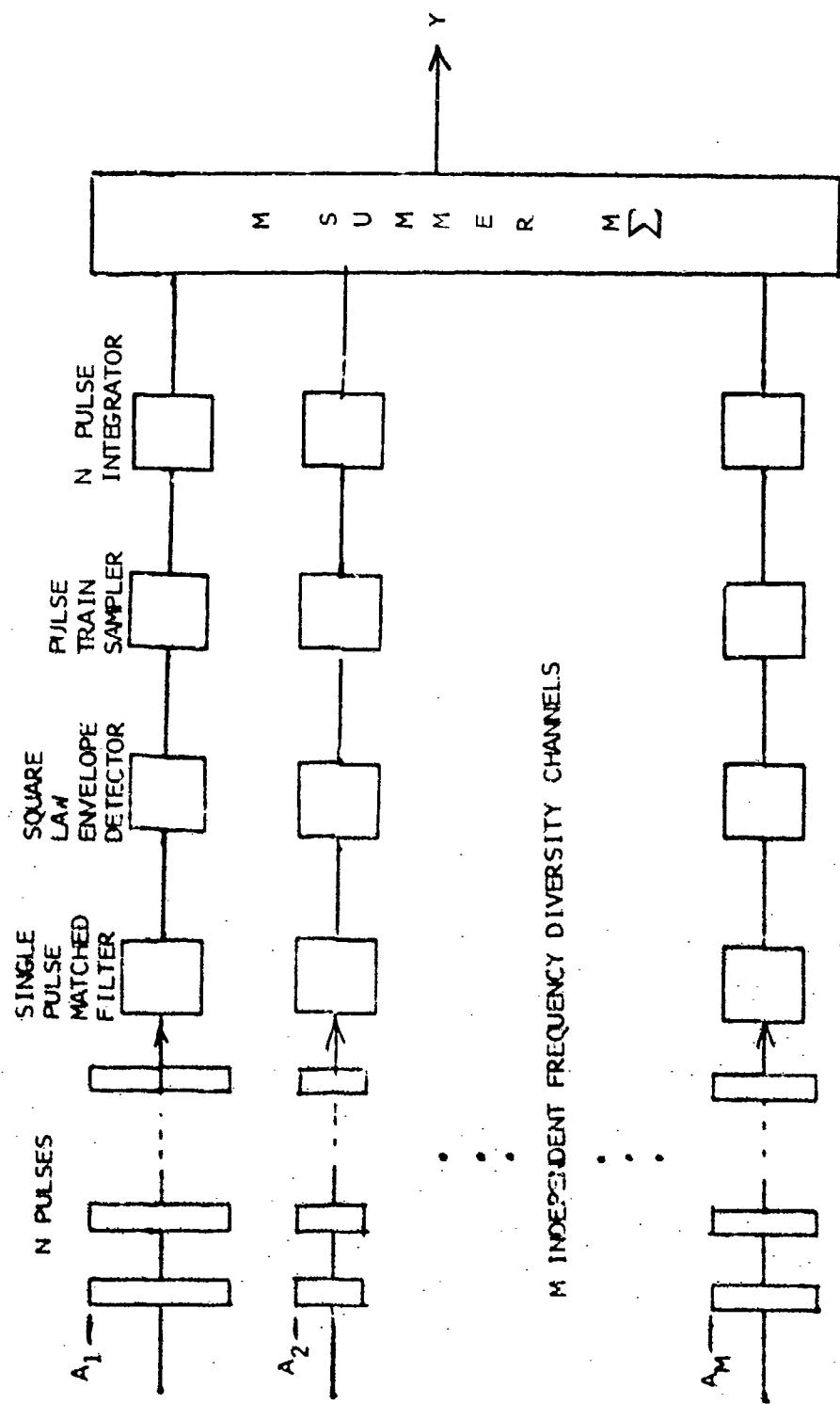


Figure A-1. M Channel MN Pulse Combiner

When we add M of these outputs through the adder,

$$Y = \sum_{i=1}^M Y_i \quad (A-5)$$

where Y_i having amplitude A_i is independent of $Y_j, i \neq j$, the result is

$$\overline{C_Y(\xi) A_1, A_2, \dots, A_M} = \frac{(-1)^{MN}}{(1+NA_0^2)^M \left(-\frac{1}{1+NA_0^2} + j\xi \right)^M (-1+j\xi)^{M(N-1)}} \quad (A-6)$$

$$p(Y) = p(Y; 1)$$

Probability density $p(Y)$ is obtained first by factoring (6)

$$\overline{C_Y(\xi) A_1, A_2, \dots, A_M} = \quad (A-7)$$

$$\frac{(-1)^{M-1}}{(1+NA_0^2)^{M-1} \left(-\frac{1}{1+NA_0^2} + j\xi \right)^{M-1}} \times \frac{(-1)^{M(N-1)+1}}{(1+NA_0^2) \left(-\frac{1}{1+NA_0^2} + j\xi \right) (-1+j\xi)^{M(N-1)}}$$

Next we use the results of [2] (11.2-28) which allows us to write the anti-characteristic function of the second factor of (A-7)

$$p'(Z) = \frac{\beta e^{\beta Z}}{|M(N-1) \cdot 1|! (1+\beta)^{M(N-1)}} \gamma[M(N-1), (\beta+1)Z] \quad (A-8)$$

where the substitution $\beta = -1/(1+NA_0^2)$ has been made.

The first factor in (A-7) results in $(M-1)$ -fold integration over the incomplete gamma function, $\gamma[M(N-1), (\beta+1)Z]$, of (8) with the additional multiplier β^{M-1} in order to obtain $p(Y; 1)$. The probability density function $p(Y)$ is thus written

$$p(Y) = \frac{\beta^M e^{\beta Y}}{(1+\beta)^{M(N-1)}} \int_0^Y \int_0^{Z_{M-1}} \frac{(M-1)}{(M-1)!} \int_0^{Z_2} \frac{\gamma[M(N-1), (\beta+1)Z_1]}{|M(N-1) \cdot 1|!} dZ_1 dZ_2 \dots dZ_{M-1} \quad (A-9)$$

This $(M-1)$ fold integral is evaluated by expanding the integrand [8] to the form

$$\frac{\gamma(n, x)}{(n-1)!} = 1 + (1+x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots + \frac{x^{n-1}}{(n-1)!}) e^{-x} \quad (A-10)$$

performing the integrations, and collecting terms. The result is

$$p(Y) = \frac{\beta^M e^{\beta Y}}{(1+\beta)^{MN+1}} \left\{ \frac{[(1+\beta)Y]^M}{(M+1)!} + \left(\sum_{i=0}^{M-2} (-1)^{M+1-i} \frac{(MN-2-i)!}{(MN-M+1-i)!(M+1-i)!} \frac{[(1+\beta)Y]^i}{i!} \right) + 1 e^{-(1+\beta)Y} \left(\sum_{j=0}^{MN-M-1} \frac{(MN-2-j)!}{(MN-M-1-j)!(M+1)!} \frac{[(1+\beta)Y]^j}{j!} \right) \right\} \quad (A-11)$$

The probability of detection

$$P_D = \int_{Y_h}^{\infty} p(Y) dY = 1 - \int_0^{Y_b} p(Y) dY \quad (A-12)$$

can be found in a similar manner by performing the integration and collecting terms. The expression which results can be contracted using the incomplete gamma functions expansion according to equation (A-10) to yield

$$P_D = 1 - \frac{\beta^{M+1}}{(1+\beta)^{MN+1}} \left\{ \left[\sum_{i=0}^{M-1} \left(\frac{1+\beta}{\beta} \right)^i \frac{(MN-2-i)!}{(MN-M+1-i)!(M+1-i)!} \frac{\gamma(1+i, \beta Y_b)}{i!} \right] + \beta \left[\sum_{j=0}^{MN-M-1} \left(1+\beta \right)^j \frac{(MN-2-j)!}{(MN-M-1-j)!(M+1)!} \frac{\gamma(1+j, \beta Y_b)}{j!} \right] \right\} \quad (A-13)$$

from which curves may be constructed after choosing the appropriate threshold, Y_b , from Pachares [7] tables. In using Pachares tables, the total number of pulses in corresponds to MN.

The expression in equation (A-13) resembles an expression derived by James [9] for target detection in noise when the target fading period is less than the post-detection integration and greater than the interpulse period. His expression is in terms of target, post-correlation, and noise bandwidths and with a degree of effort can be related to the topic treated in this report.

COMPUTATIONAL RESULTS AND CHECKING WITH OTHER RESULTS

Equation (A-13) is used to compute the curves in Figures A-2 and A-3. These figures present the probability of detection versus single pulse rms signal-to-noise ratio for different combinations of correlated pulses per channel, N, and number of diversity channels, M. Each figure shows a family of curves for a given false alarm probability. Note that these curves fall between the two extreme cases, i.e., when M = 1, Swerling Case I and N = 1, Swerling Case II, as presented in D'Antonio and Rubin [2]. The curves for Case I, M = 1 and Case II, N = 1 have been repeated here and as expected they check with those of the above reference. The 3 dB discrepancy between the curves presented herein and those of D'Antonio and Rubin is due to the fact that we are plotting p_D against the average signal-to-noise ratio A_0 rather than the average of the peak $\bar{G}_p = 2A_0$ of that reference. The points on Figures A-2 and A-3 are computed using Barton's [5] paper. Note the agreement of these points with the curves which were plotted using equation (A-13). Regions of departure occur at high probabilities of detection as well as low probabilities.

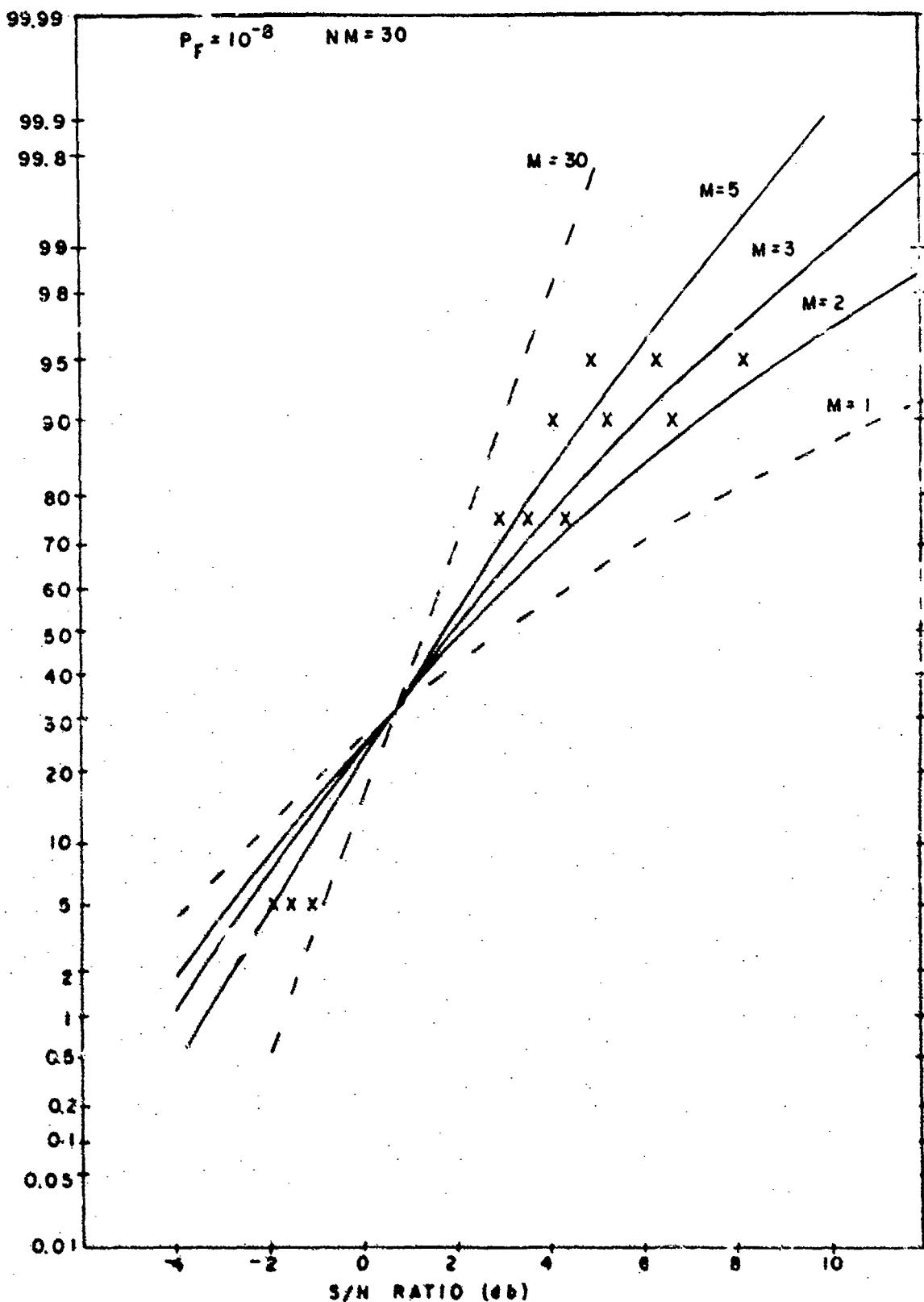


Figure A-2. Probability of Detection for Six Block Correlated Pulses

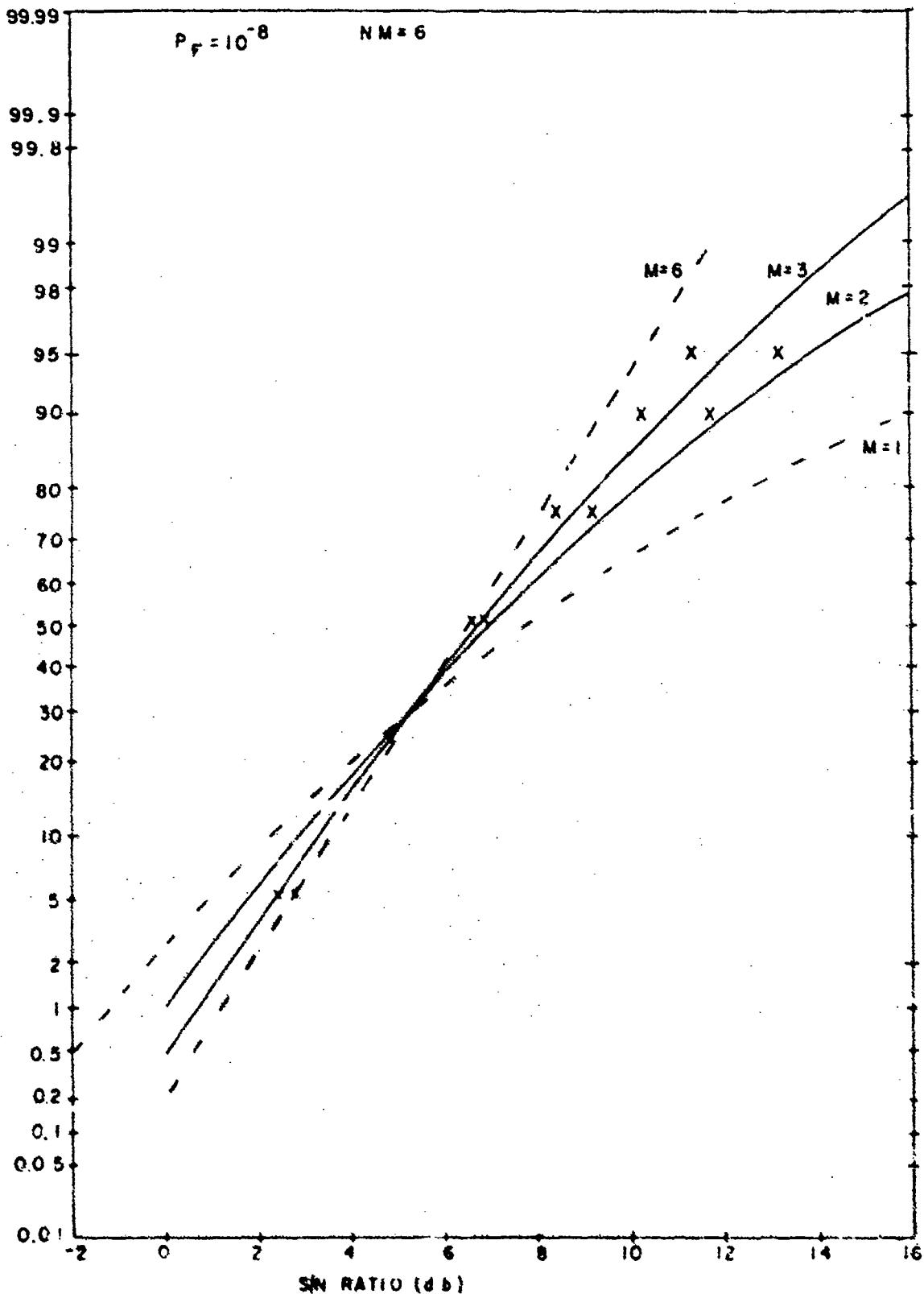


Figure A-3. Probability of Detection for Thirty Block Correlated Pulses.

The computer programming ran into some accuracy difficulties when the number of channels M was made large. This was due largely to overflows and underflows encountered in the terms of equation (A-13). A discussion on this topic is presented in Appendix C authored by E. Bromley who did all the programming for obtaining the numerical results reported herein.

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APPENDIX B
**DERIVATION OF PROBABILITY OF DETECTION
FOR THE FOUR MTI RECEIVER CASES**

by

Vincent Vannicola

This Appendix presents the derivation of the probability density function of the variable ℓ_i and computation of the threshold γ_i for each receiver case.

The receiver cases are shown in Figure 3 of the basic report. The input into each port is a zero mean Gaussian random variable with variance σ^2 . (This variance may be either σ_0^2 or σ_1^2 depending on H_0 or H_1 .) For simplicity let us denote the inputs by x_1, x_2, \dots . Then the input pdf at each port is

$$p_{x_i}(X) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{x^2}{2\sigma^2}\right) \quad (B-1)$$

(a) The pdf of the output of the absolute value is obtained as follows

$$p_{|X|}(|X|) = |J| p_x(X) \begin{cases} + |J| p_x(X) & |x| > 0 \\ & |x| < 0 \end{cases} \quad (B-2)$$

where

$$|J| = \left| \frac{\partial x}{\partial |X|} \right| = 1$$

Letting $u = |X| = |-X|$ we have

$$p_u(u) = \sqrt{\frac{2}{\pi}} \frac{1}{\sigma} \exp\left(-\frac{u^2}{2\sigma^2}\right) : u \geq 0 \quad (B-3)$$

$$p_u(u) = 0 : u < 0$$

Since ℓ_1 is the sum of the two independent variables u_1 and u_2 we may obtain the pdf of ℓ_1 through the convolution integral

$$\begin{aligned} p_{\ell_1}(\ell_1) &= \int_{-\infty}^{\infty} p_u(\ell_1 - u) p_u(u) du \\ &= \frac{2}{\pi\sigma^2} \int_0^{\ell_1} \exp\left(-\frac{[\ell_1 - u]^2 + u^2}{2\sigma^2}\right) du \\ &= \frac{2}{\sqrt{\pi\sigma^2}} \exp\left(-\frac{\ell_1^2}{4\sigma^2}\right) \operatorname{erf}\left(\frac{\ell_1}{2\sigma}\right) \end{aligned} \quad (B-4)$$

It can be seen that this expression is found in (7-A) of the report.

In order to determine the threshold, the false alarm probability must be evaluated using the integral

$$P_F = \int_{\gamma_1}^{\infty} p_{\ell_1}(\ell_1) d\ell_1 = \frac{2}{\sqrt{\pi\sigma}} \int_{\gamma_1}^{\infty} \operatorname{erf}\left(\frac{\ell_1}{2\sigma_0}\right) \exp\left(-\frac{\ell_1^2}{4\sigma_0^2}\right) d\ell_1$$

$$= \int_{\gamma_1}^{\infty} \operatorname{erf}^2\left(\frac{\ell_1}{2\sigma_0}\right) d\ell_1 = 1 - \operatorname{erf}^2\left(\frac{\gamma_1}{2\sigma_0}\right) \quad (B-5)$$

For $P_F = 5 \times 10^{-7}$ we have

$$P_F = 1 - \operatorname{erf}^2\left(\frac{\gamma_1}{2\sigma_0}\right) = 5 \times 10^{-7}$$

$$P_F = [1 + \operatorname{erf}\left(\frac{\gamma_1}{2\sigma_0}\right)] [1 - \operatorname{erf}\left(\frac{\gamma_1}{2\sigma_0}\right)] = 5 \times 10^{-7} \quad (B-6)$$

We see that $\operatorname{erf}\left(\frac{\gamma_1}{2\sigma_0}\right)$ is almost unity so (B-6) reduces to

$$\operatorname{erfc}\left(\frac{\gamma_1}{2\sigma_0}\right) = 2.5 \times 10^{-7} \quad (B-7)$$

Solving for γ_1 [1-B], the threshold, we get

$$\gamma_1 = 3.65 (2\sigma_0) = 7.30 \sigma_0 \quad (B-8)$$

which agrees with (12-A).

The detection probability is obtained by evaluating the same integral in (B-5) except that the variance is different.

$$P_D = \int_{\gamma_1}^{\infty} \operatorname{erf}^2\left(\frac{\ell_1}{2\sigma_1}\right) d\ell_1 = 1 - \operatorname{erf}^2\left(\frac{\gamma_1}{2\sigma_1}\right) \quad (B-9)$$

which is of the form corresponding to (14-A).

(b) This case is simply the sum of the square of two statistically zero mean Gaussian random variables.

$$\ell_2 = X_1^2 + X_2^2 \quad (B-10)$$

Its probability density function is derived in many textbooks. Since it is simple to derive we will go through the basic steps here. We set

$$\ell_2 = X_1^2 + X_2^2 \quad X_1 = \sqrt{\ell_2} \cos \theta$$

$$\theta = \tan^{-1} \left(\frac{X_2}{X_1} \right) \quad X_2 = \sqrt{\ell_2} \sin \theta$$

giving a Jacobian $|J| =$

$$|J| = \begin{vmatrix} \frac{1}{2\sqrt{\ell_2}} \cos \theta & \frac{1}{2\sqrt{\ell_2}} \sin \theta \\ -\frac{1}{2\sqrt{\ell_2}} \sin \theta & \frac{1}{2\sqrt{\ell_2}} \cos \theta \end{vmatrix} = \frac{1}{2} \quad (B-11)$$

The transformation may be written

$$p_{\ell_2|\theta}(\ell_2, \theta) = |J| p_{X_1, X_2}(X_1, X_2) = \frac{1}{4\pi\sigma^2} \exp\left(-\frac{\ell_2}{2\sigma^2}\right) \quad (B-12)$$

The pdf of ℓ_2 is then evaluated

$$p_{\ell_2}(\ell_2) = \int_0^{2\pi} p_{\ell_2|\theta}(\ell_2, \theta) d\theta = \frac{1}{2\sigma^2} \exp\left(-\frac{\ell_2}{2\sigma^2}\right) \quad (B-13)$$

and is in agreement with (7-B).

In a manner similar to finding threshold and detection probability of case (a) we may write

$$P_F = \int_{\gamma_2}^{\infty} p_{\ell_2}(\ell_2) d\ell_2 = \left[-e^{-\frac{\ell_2}{2\sigma_0^2}} \right]_{\gamma_2}^{\infty} = e^{-\frac{\gamma_2}{2\sigma_0^2}} = 5 \times 10^{-7} \therefore \gamma_2 = 29\sigma_0^2 \quad (B-14)$$

which agrees with (12-B), and

$$P_D = \left[-\exp\left(-\frac{\ell_2}{2\sigma_1^2}\right) \right]_{\gamma_2}^{\infty} = \exp\left(\frac{\gamma_2}{2\sigma_1^2}\right) \quad (B-15)$$

which corresponds to (14-B).

(c) To start with we may use the results of case b which have just developed. The pdf for $y^2 = \ell_2$ is equation (7-B).

$$p_{y^2}(y^2) = \frac{1}{2\sigma^2} \exp\left(-\frac{y^2}{2\sigma^2}\right) \quad (B-16)$$

and through a simple transformation

$$|J| = \frac{\partial y^2}{\partial y} = 2y$$

we see as expected that y has a Rayleigh distribution

$$p_y(y) = |\mathbf{J}| p_{y^2}(y^2) = \frac{y}{\sigma^2} \exp\left(-\frac{y^2}{2\sigma^2}\right) \quad (\text{B-17})$$

Now the pdf of

$$\ell_3 = y_1 + y_2 \quad (\text{B-18})$$

where the y variables are statistically independent is found through the convolution integral

$$\begin{aligned} p_{\ell_3}(\ell_3) &= \int_{-\infty}^{\infty} p_y(y) p_y(\ell_3 - y) dy \\ &= \int_0^{\ell_3} \frac{y}{\sigma^2} \exp\left(-\frac{y^2}{2\sigma^2}\right) \left[\frac{\ell_3}{\sigma^2} - \frac{y}{\sigma^2}\right] \exp\left(-\frac{\ell_3 - y}{2\sigma^2}\right)^2 dy \\ &= \frac{\ell_3}{2\sigma^2} \exp\left(-\frac{\ell_3^2}{2\sigma^2}\right) + \frac{\sqrt{\pi}}{2\sigma} \frac{(\ell_3^2 - 1)}{2\sigma^2} \exp\left(-\frac{\ell_3^2}{4\sigma^2}\right) \operatorname{erf}\left(\frac{\ell_3}{2\sigma}\right) \end{aligned} \quad (\text{B-19})$$

This is an agreement with (7-C).

The false alarm probability is derived by integrating (B-19).

$$P_F = \int_{\gamma_3}^{\infty} p_{\ell_3}(\ell_3) d\ell_3 \quad (\text{B-20})$$

The integration may be simplified by a change in variables

$$a = \frac{\ell_3}{2\sigma}$$

giving

$$P_F = \int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a \exp(-2a^2) da + \sqrt{\pi} \int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a^2 \exp(-a^2) \operatorname{erf}(a) da - \sqrt{\pi} \int_{\frac{\gamma_3}{2\sigma}}^{\infty} \exp(-a^2) \operatorname{erf}(a) da \quad (\text{B-21})$$

The first integral of (B-21) is

$$\int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a \exp(-2a^2) da = -\frac{1}{2} \left[\exp(-2a^2) \right]_{\frac{\gamma_3}{2\sigma}}^{\infty}$$

the second integral is

$$\begin{aligned} & \sqrt{\pi} \int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a^2 \exp(-a^2) \operatorname{erf}(a) da \\ &= -\sqrt{\pi} \left[a \exp(-a^2) \operatorname{erf}(a) + \frac{\pi}{4} \right]_{\frac{\gamma_3}{2\sigma}}^{\infty} \operatorname{erf}^2(a) \cdot \frac{1}{2} \left[\exp(-2a^2) \right]_{\frac{\gamma_3}{2\sigma}}^{\infty} \end{aligned}$$

and the third is

$$-\sqrt{\pi} \int_{\frac{\gamma_3}{2\sigma}}^{\infty} a \exp(-a^2) \operatorname{erf}(a) da = -\frac{\pi}{4} \left[\operatorname{erf}^2(a) \right]_{\frac{\gamma_3}{2\sigma}}^{\infty}$$

Combining we have

$$\begin{aligned} P_F &= -\sqrt{\pi} \left[a \exp(-a^2) \operatorname{erf}(a) \cdot \exp(-2a^2) \right]_{\frac{\gamma_3}{2\sigma}}^{\infty} \\ &= \sqrt{\pi} \frac{\gamma_3}{2\sigma_0} \exp\left(-\frac{\gamma_3^2}{4\sigma_0^2}\right) \operatorname{erf}\left(\frac{\gamma_3}{2\sigma_0}\right) + \exp\left(-\frac{\gamma_3^2}{2\sigma_0^2}\right) \end{aligned} \quad (B-22)$$

which is in agreement with (11-C).

To find the threshold γ_3 we set P_F equal to 5×10^{-7} and note that for the large value of γ_3 which satisfies this condition the following approximation holds:

$$a \exp(-a^2) \approx \frac{1}{\sqrt{\pi}} \quad 5 \times 10^{-7} \quad (B-23)$$

Equation (B-23) may be put into logarithmic form giving

$$a^2 = \varrho_H(a) + 15.0$$

and through trial and error we find this relation to be satisfied when

$$a = \frac{\gamma_3}{2\sigma_0} = 4.05$$

$$\gamma_3 = 8.1 \sigma_0 \quad (B-24)$$

which agrees with (12-C).

The detection probability is simply

$$P_D = \sqrt{\pi} \frac{\gamma_3}{2\sigma_1} \exp\left(-\frac{\gamma_3^2}{4\sigma_1^2}\right) \operatorname{erf}\left(\frac{\gamma_3}{2\sigma_1}\right) + \exp\left(-\frac{\gamma_3^2}{2\sigma_1^2}\right) \quad (\text{B-25})$$

in agreement with (14-C).

(d) For this receiver case the variable ℓ_4 is the sum of two independent variables y_1^2 and y_2^2 each having probability density function as that for ℓ_2 of case (b) given in equation (B-13).

$$p_{\ell_2}(\ell_2) = \frac{1}{2\sigma^2} \exp\left(-\frac{\ell_2}{2\sigma^2}\right)$$

Since

$$\ell_4 = y_1^2 + y_2^2 \quad (\text{B-26})$$

and

$$p_{y_1^2}(y^2) = p_{y_2^2}(y^2) = p_{\ell_2}(y^2) = p_{\ell_2}(\ell_2) \quad (\text{B-27})$$

for $\ell_2 = y_2$ the probability density function of ℓ_4 may be derived from the convolution integral

$$\begin{aligned} p_{\ell_4}(\ell_4) &= \int_0^{\ell_4} \frac{1}{2\sigma^2} \exp\left(-\frac{\ell_2}{2\sigma^2}\right) \frac{1}{2\sigma^2} \exp\left(-\frac{\ell_4 - \ell_2}{2\sigma^2}\right) d\ell_2 \\ &= \frac{1}{4\sigma^4} \exp\left(-\frac{\ell_4}{2\sigma^2}\right) \int_0^{\ell_4} d\ell_2 \\ &= \frac{\ell_4}{4\sigma^4} \exp\left(-\frac{\ell_4}{2\sigma^2}\right) \end{aligned} \quad (\text{B-28})$$

giving the same expression as in (7-D).

This is recognized as a chi square distribution with four degrees of freedom as should be expected.

Now the false alarm probability is

$$\begin{aligned} P_F &= \int_{\gamma_4}^{\infty} p_{\ell_4}(\ell_4) d\ell_4 = \int_{\gamma_4}^{\infty} \frac{\ell_4}{4\sigma^4} \exp\left(-\frac{\ell_4}{2\sigma^2}\right) d\ell_4 \\ &= 1 - \frac{\ell_4}{2\sigma} \exp\left(-\frac{\ell_4}{2\sigma^2}\right) + \int_{\gamma_4}^{\infty} \frac{1}{2\sigma^2} \exp\left(-\frac{\ell_4}{2\sigma^2}\right) d\ell_4 \end{aligned} \quad (\text{B-29})$$

$$= \left(\frac{\gamma_4}{2\sigma_0^2} + 1 \right) \exp \left(-\frac{\gamma_4}{2\sigma_0^2} \right)$$

which corresponds to equation (11-D).

The threshold may be evaluated by setting

$$P_F = \left(\frac{\gamma_4}{2\sigma_0^2} + 1 \right) \exp \left(-\frac{\gamma_4}{2\sigma_0^2} \right) = 5 \times 10^{-7}$$

or in logarithmic form letting $a = \frac{\gamma_4}{2\sigma_0^2}$

$$a = \ln(a+1) \cdot \ln 5 + 7 \ln 10$$

$$a = \ln(a+1) + 14.5$$

and solving for

$$a = 17.5$$

we have

$$\gamma_4 = 35 \sigma_0^2 \quad (B-29)$$

which corresponds to equation (12-D).

The detection probability is obtained by substituting into equation (B-29) σ_1^2 for σ_0^2 and the value for γ_4 of (B-30) and results in

$$P_D = \left(\frac{\gamma_4}{2\sigma_1^2} + 1 \right) \exp \left(-\frac{\gamma_4}{2\sigma_1^2} \right) \quad (B-31)$$

This corresponds to equation (14-D).

REFERENCES

- 1-B M. Abramowitz and I.A. Stegun, Handbook of Mathematical Functions, Washington, D.C., National Bureau of Standards, 1965.

APPENDIX C

COMPUTATIONAL PROCEDURE FOR PROBABILITIES OF DETECTION

by

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The expression for the probability of detection is given by equation (A-13)

$$P_D = 1 - \frac{\beta^m}{\rho(Nm + N - 1)} \left[\sum_{i=0}^m \left(\frac{\rho}{\beta} \right)^i \frac{(n+m-i-1)!}{(n-1)!(m-i)!} \frac{\gamma(i+1, \beta Y_0)}{i!} \right. \\ \left. + \beta \sum_{j=0}^{n-1} \rho^j \frac{(n+m-j-1)!}{(n-j-1)! m!} \frac{\gamma(j+1, Y_0)}{j!} \right] \quad (C-1)$$

where $m = M - 1$

$$n = M(N - 1)$$

$$\beta = \frac{1}{1 + NA_0^2}$$

$$\rho = \beta + 1$$

$\gamma(k, x)$ = incomplete gamma function

The evaluation of this function presents some computational difficulties which were not entirely resolved in the time available. For typical values of the parameters many of the quantities (the factorials, β^m , or $\gamma(k, x)$) become greater than 10^{38} or less than 10^{-38} and exceed the capacity of the computer. This problem was overcome very simply by taking logarithms. However, for cases involving relatively large m and low S/N ratio the numbers comprising the summations become very large and opposite in sign. For example, for $m = 14$ and $N = 2$ the largest terms are on the order of 10^{20} . Since the final answer is a probability, it must lie between 0 and 1. As such more than 20 place accuracy is required in the terms of the summations, whereas single precision on a computer offers only 8 places. Also, much greater accuracy can be required for other combinations of the parameters.

For the present we have not included results over the entire range of interest of all the variables. It is expected, however, that the expression could be rewritten or re-expressed to be compatible with the limitations of the computer. The following is a listing of the actual Fortran Program used to calculate the results.

```

10 COMMON FAC(400),H(200),GAM2(2,200),ISIG(200)
20 COMMON PDT(30),Y0(30,5),NPR(30,36),NP(30),A(20)
60 READ: NT
70 READ: NC
80 DO 8 I=1,NC;8 READ: (Y0(I,J),J=1,5)
90 READ: (NP(I),I=1,NC)
100 DO 10 I=1,NC;NPAIR=2*NP(I)
110 10 READ: (NPR(I,K),K=1,NPAIR)
120 DO 55 I=1,9;55 A(I)=2.*I-10.
130 ISIG(1)=1
140 DO 81 I=2,NT;J=I-1;81 ISIG(I)=-1*ISIG(J)
150 8 FORMAT (3X,F12.4,6X,I2,6X,I3,6X,F7.2,6X,F12.8)
160  FAC(1) = 0.
170  FAC(2)=0.
180 DO 80 I=3,NT
190 J=I-1
200 89  FAC(I)=FAC(J)+ALOG(FLOAT(J))
210 DO 6 I1=1,NC;NPAIR=2*NP(I1)
220 DO 6 K=2,NPAIR,2;K1=K-1;M=NPR(I1,K1);N=NPR(I1,K);XN=N
222 PRINT 102,N,M;102 FORMAT (" FOR N =",I3," AND M =",I3)
229 PRINT 103,(A(I),I=1,9);PRINT 120;120 FORMAT ("0")
230 DO 6 J=1,5;Y=Y0(I1,J)
233 104 FORMAT (""                                     < S/N RATIO (DB) >")
236 103 FORMAT (" Y   ",9F6.8)
240 M=NPR(I1,K1);N=NPR(I1,K);XN=N
244 DO 5 MI=1,9;A2=0.
246 A0=10.**(A(M1)/20.)
248 BETA=-1./((1.+XN*A0*A0))
250 P=-BETA*Y
252 MS=M+1;CALL GA(8,MS,P)
253 B1=ALOG(-BETA)
258 NS=(M+1)*(N-1);ROA=BETA+1.;RI=ALOG(ROA)
260 N6=N*N+N-1
270 IF(M1.EQ.1) CALL GA(1,NS,Y)
272 DO 4 I=1,NS;IA=I-1;M12=M+2;M13=ISIG(M12)
274 H2=ALOG(FAC2(NS,M,IA))
276 H3=(M+1)*B1;H4=(N6-IA)*RI
278 A7=H3-H4+GAM2(1,1)*H2;IF(ABS(A7).GT. 50.) GOTO 4
280 A2=A2+M13*EXP(A7);4 CONTINUE

```

READY

*

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330 MS=M+13 DO 3 I=1,MS;IA=I-1;M10=M-IA+1
344 G2=ALOG(FAC1(NS,M,IA))
345 G3=(M-IA)*B1;G4=(N6-IA)*R1
350 A6=G3-G4+GAM2(2,I)+G2;IF(ABS(A6).GT.50.) GOTO 3
360 A2=A2+ISIG(M10)*EXP(A6); 3 CONTINUE
620 IF(ABS(A2).GT. 50.) A2=-50.
630 PD=1.0-A2
640 PDT(M1)=PD$5 CONTINUE;PRINT 89,Y,(PDT(J8),J8=1,9)
650 89 FORMAT (F7.2,1X,9F6.3)
660 6 CONTINUE
670 STOP;END
680 FUNCTION FAC1(NS,M,IA)
690 N = M - IA
700 P = 1.
710 DO 10 I = 1,N
720 10 P = P*(NS-I+I)/I
730 FAC1 = P
740 IF(M .EQ. IA) FAC1 = 1.
750 RETURN
760 END
770 FUNCTION FAC2(NS,M,IA)
780 N = M
790 P = 1.
800 DO 10 I = 1,N
810 10 P = P*(NS-IA-I+I)/I
820 FAC2 = P
830 IF(M .EQ. 0) FAC2 = 1.
840 RETURN
850 END
1000 SUBROUTINE GA(I3,NS,X)
1005 COMMON FAC(400),H(200),GAM2(2,200)
1010 C=ALOG(X)
1020 NMAX=2.*X+10.;IF(NMAX.GT.30) NMAX=30
1030 IMAX=NS+NMAX;XN=1.5*X
1040 DO 10 I=1,IMAX;IA=I-1
1050 10 H(I)=IA+C-X-FAC(I);HS=1.0
1060 DO 80 I=1,NS;GAM2(I3,I)=0.
1070 G3=I
1080 IF(XN.GT.G3) GOTO 80
1090 J=I+1;J1=J+NMAX-1;H8=H(J);GAM=0.
1100 DO 30 K=J,J1
1110 H1=H(K)-H8;IF(ABS(H1).GT.50.) GOTO 30
1120 GAM=GAM+EXP(H1)
1130 GAM2(I3,I)=ALOG(GAM)+H8
1140 30 CONTINUE;GO TO 20
1150 20 IF(ABS(H(I)).GT.50.) GOTO 20
1160 HS=HS-EXP(H(I))
1170 GAM2(I3,I)=ALOG(HS)
1180 20 CONTINUE;RETURN;END

```

READY

*